

**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET**

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ACRONYMS

AMR	Analysis/Model Report
BDCF	Biosphere Dose Conversion Factor
CRWMS	Civilian Radioactive Waste Management System
DOE	U.S. Department of Energy
K_d	Soil Solid/Liquid Partition Coefficient
M&O	Management and Operating Contractor
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management System
PA	Performance Assessment
SZ	Saturated Zone
T-Value	Soil Loss Tolerance Value
TDMS	Technical Database Management System
TIC	Technical Information Center
TSPA&I	Total System Performance Assessment and Integration
TSPA-SR	Total System Performance Assessment - Site Recommendation
TSPA-VA	Total System Performance Assessment - Viability Assessment
USDA	United States Department of Agriculture
USDA NRCS	United States Department of Agriculture Natural Resource Conservation Service
UZ	Unsaturated Zone

1. PURPOSE

This activity will determine reasonable and conservative bounding estimates of annual surface soil removal representative of the major soils present in the vicinity of the projected reference critical group within the Amargosa Valley. Leaching coefficients appropriate for the various radionuclide elements that will be considered in the *Total System Performance Assessment-Site Recommendation* (TSPA-SR) dose calculations carried out in the Repository Integration Program (RIP) code (Golder 1998) will also be determined in the work activity. The analyses are needed to address concerns raised by review groups, including the U.S. Nuclear Regulatory Commission (NRC) and the Performance Assessment Peer Review Panel (PAPRP), and the U.S. Department of Energy (DOE) Management Technical Service (MTS), that the potential impact of radionuclide accumulation in soils subjected to long-term continuous irrigation with contaminated water was not addressed in the *Total System Performance Assessment-Viability Assessment* (TSPA-VA), (CRWMS M&O 1998). The soil removal analysis reported in this Analysis/Model Report are applicable to both existing agricultural and domestic use soils and soils conditions subsequently modified by thin deposits of volcanic ash (i.e., ash deposits less than one centimeter thick); the analysis does not address the future soil conditions resulting from the deposition of thick ash deposits (e.g., >1.0 cm).

The Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) Performance Assessment Organization will use radionuclide-specific biosphere dose conversion factors (BDCFs) to calculate potential radiation doses to a hypothetical human receptor group as part of the post-closure TSPA for the Site Recommendation (SR). Possible effects of soil radionuclide build-up on BDCFs generated by the computer code GENII-S (Leigh et al. 1993) will be evaluated by subsequent analysis, and the soil removal estimates derived from this Analysis/Model Report (AMR) analysis will be used as input for the comprehensive radionuclide build-up assessment. Additionally, the soil loss estimates derived from the analysis will be used in subsequent dose calculations for the radionuclide-contaminated ash deposition scenario. The parameters used to calculate the annual soil depth reduction estimates and radionuclide-element leaching coefficients will be placed in the Technical Data Management System (TDMS) along with required documentation in accordance with AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System*.

The two major removal processes evaluated in this analysis are:

1. Surface Soil Erosion Rate. The annual reduction (cm/yr) of surface soil by the combined processes of both wind and water erosion. In this analysis the quantity (kg) of soil removed from a given area (ha) of land per year (yr) will be used to calculate the annual depth (cm) reduction of surface soil.
2. Leaching. The downward movement of substances, including radionuclides, dissolved in percolating waters. In this analysis, the leaching coefficient ($\lambda \text{ yr}^{-1}$) will be determined for 27 different elements.

The purpose for the annual soil depth reduction estimates is to couple these with the radionuclide input quantities from irrigation with contaminated groundwater in a separate abstraction analysis to determine the net build-up (inputs minus outputs) of radionuclides.

The purpose for the leaching analysis is to develop more site-specific values for these parameters than exist as default data in the GENII-S code, i.e., specific for the soil properties and principal land use practices (alfalfa production) existing in the Amargosa Valley. The leaching coefficients derived from this analysis will be used in the development of BDCFs for both the non-disruptive and selected disruptive event scenarios. The 27 elements (isotope independent) considered in the analysis were selected from the list of radionuclide elements modeled in TSPA-VA (CRWMS M&O 1998a) and additional elements subsequently screened-in through an analysis to determine which radionuclides should be included in the total system performance assessment for site recommendation based on their potential contribution to dose (TSPA-SR) calculations (CRWMS M&O 1999a).

In these analyses, two estimates were developed for each of the two processes. First, a “reasonable representative” or “best” estimate was developed for each. This estimate is defined as one being reasonably expected to occur based on the soil properties and land use characteristics of the critical group (Dyer 1999, Section 115) proposed by the Nuclear Regulatory Commission (NRC) (64 FR 8640). The conservative bounding estimate is a “high dose-yielding bounding value” calculated under the conditions that would potentially result in higher exposure rates. These analyses were conducted according to the Development Plan entitled *Evaluation of Soil/Radionuclide Removal by Erosion and Leaching, Rev. 0*, (CRWMS M&O 1999b).

The soil removal analysis is constrained by the assumption that current land use practices result in annual soil depletion due to accelerated erosion (Section 5.1) and does not consider possible accretion due to aeolian and/or alluvial processes that might result in transport of soil material and/or radionuclide contaminants to the site of consideration. Both the soil removal estimates and the calculated leaching coefficients are limited to sandy-textured soils and are therefore not applicable to finer-textured soils that might be present as minor inclusions in the soil mapping units considered in the analyses.

2. QUALITY ASSURANCE

This AMR has been determined to be Quality Affecting in accordance with QAP-2-0, *Conduct of Activities*. The activity evaluation (CRWMS M&O 1999c) determined that the information will be used to support Performance Assessment and it supports other quality-affecting activities. Therefore, this AMR is subject to the requirements of the *Quality Assurance Requirements and Description* (QARD) document (DOE 2000).

Preparation of the AMR did not require the classification of items in accordance with CRWMS M&O procedure QAP-2-3, *Classification of Permanent Items*. The analyses conducted were not field activities. Therefore, a Determination of Importance Evaluation in accordance with CRWMS M&O procedure NLP-2-0 *Determination of Importance Evaluations* was not required. The governing procedure for preparation of this AMR is OCRWM procedure AP-3.10Q, *Analyses and Models*.

3. COMPUTER SOFTWARE AND MODEL USAGE

No models were used or developed in this analysis. The leaching analyses included the use of a FORTRAN routine (consisting of several modules) developed in accordance with AP-SI.1Q, *Software Management* (Section 5.1, Control of Software Routines and Macros). The software routine developed, SOIL_MODEL, version A1.20, was developed with FORTRAN 77. Attachment II includes the Software Routine Verification documentation (McCurley 1999a) and a hard-copy of the routine's source code listing (McCurley 1999b). The routine was used with specific values of input parameters (Tables 2 and 3, all positive numbers). As can be readily verified by executing Equation 1 (Section 6.2) with the use of a hand calculator, the macro produces the correct results for all specified input parameters.

4. INPUTS

4.1 DATA AND PARAMETERS

The following two sections contain a brief summary and listing of the input data and parameters used in the calculations for the analysis of the two radionuclide removal processes from the surface soil.

4.1.1 Surface Soil Erosion Analysis – Data/Parameter Inputs

Soil loss tolerance (T), sometimes called permissible soil loss, is defined as the maximum annual rate of soil erosion that can occur while still maintaining productivity indefinitely (Troeh et al. 1980, p. 149). T -value indices have been established for all major soils occurring across the United States to serve as a guideline for land owner/managers to manage their practices in such a manner as to sustain agricultural production over time. A single T -value is assigned to each soil type, or soil series (Brady 1984, p. 434) occurring within an agricultural field or applicable land unit. The soil's surface horizon bulk density was employed to calculate the mass quantity of annual soil loss per unit area of land (represented by the T -value) to an annual soil depth reduction (Section 6.1.1).

Table 1 lists T -values and soil bulk density value ranges for the soils occurring in the major mapping units in the vicinity of Lathrop Wells, NV which is the location of the specified farming critical group (Dyer 1999, Section 115 – Required characteristics of the reference biosphere and critical group). These soil data were extracted from a database maintained at the Las Vegas, NV field office of the U.S. Department of Agriculture Natural Resource Conservation Service (SN9912USDASOIL.000). The six soil series comprising the specific mapping units were taken from existing soil maps of the Amargosa Valley (CRWMS 1999c, Figure 1, pp. 2-3). Assumptions and justification for the use of these input parameters are discussed in Section 5.1.

4.1.2 Leaching Analysis – Data/Parameter Inputs

The soil bulk density (ρ) input parameter value used in the leaching coefficient calculations (Table 2) is the approximate mean value of the soil bulk density range associated with all six soils listed in Table 1. The annual precipitation (P), annual irrigation (I), and annual evapotranspiration (E) input parameter values are those values associated with alfalfa production in the Amargosa Valley. The element-specific soil/liquid partition coefficients (K_d values) listed

in Table 3 are the values recommended by Sheppard and Thibault (1990, Tables 1, 3, and A-1) for sandy loam-textured soils. Justification for the use of these inputs, as well as assumptions on their appropriateness for use in the analysis, are discussed in Section 5.2.

Table 1. Soil Loss Tolerance (T) and Surface Horizon Soil Bulk Density (ρ) Values Assigned to the Soil Series Comprising the Mapping Units Used for Agricultural Production in the vicinity of Lathrop Wells, NV.

Soil Series ^a	Soil Loss Tolerance Factor, (T) (t/ ha/yr)	Soil Bulk Density (ρ) ^b (g/cm ³)	DTN
Arizo	11.21	1.40 – 1.55	SN9912USDASOIL.000
Commski	11.21	1.40 – 1.60	SN9912USDASOIL.000
Corbilt	8.97	1.35 – 1.50	SN9912USDASOIL.000
Sanwell	11.21	1.40 – 1.60	SN9912USDASOIL.000
Shamock	4.48	1.50 – 1.70	SN9912USDASOIL.000
Yermo	11.21	1.40 – 1.60	SN9912USDASOIL.000

Notes: ^a Data extracted from CRWMS M&O (1999c), Figure 1, pp. 2-3 and Appendix C.

^b DTN SN9912USDASOIL.000, Moist Soil Bulk Density Value.

Table 2. Summary of Generic (e.g., not radionuclide-specific) Inputs Used in the Leaching Analysis

Analysis Parameter	Input	DTN
Soil Bulk Density (ρ)	1.50 g/cm ³ ^a	SN9912USDASOIL.000
Annual Precipitation (P)	10.24 cm/yr ^b	MO9903CLIMATOL.001
Irrigation Rate (I)	240.44 cm/yr ^c	MO9912SPAIN06.033
Annual Evapotranspiration (E)	235.43 cm/yr ^d	MO9912MWDEEA06.003

NOTES: ^a Mean value used as a “generic” soil bulk density for the purpose of this analysis. The value is calculated by summing the mid-range values for all six soil series listed in Table 1 and taking the average of these six values.

^b Value is calculated by summing the average monthly precipitation (inches) for Site 9 listed in MO9903CLIMATOL.001 and multiplying by 2.54 for conversion to metric units (cm).

^c Value is calculated by multiplying the *Milk (Alfalfa) Irrigation Rate* parameter (94.66 inches) listed in MO9912SPAIN06.033 by 2.54 for conversion to metric units (cm).

^d Value is calculated by multiplying the *Annual Evapotranspiration* parameter (92.69 inches) listed in MO9912MWDEEA06.003 by 2.54 for conversion to metric units (cm).

Table 3. Radionuclide Element-Specific Soil Solid/Liquid Partition Coefficients, K_d values, Used in the Calculation of Leaching Coefficients.

Element	K_d (Best Estimate) (L/kg)	K_d (Conservative Estimate) (L/kg)	DTN and Source Table
C	5.00E+00	7.10E+00	SN0002KDVALUES.000, Tables 1 & A-1
Ni	4.00E+02	3.60E+03	SN0002KDVALUES.000, Table 3
Se	5.50E+01	7.00E+01	SN0002KDVALUES.000, Table 3
Sr	1.50E+01	1.90E+02	SN0002KDVALUES.000, Table 3
Y	1.70E+02	— ^a	SN0002KDVALUES.000, Table 1
Mo	1.00E+01	5.20E+01	SN0002KDVALUES.000, Table 3
Zr	6.00E+02	— ^a	SN0002KDVALUES.000, Table 1
Nb	1.60E+02	— ^a	SN0002KDVALUES.000, Table 1
Tc	1.00E-01	1.60E+01	SN0002KDVALUES.000, Table 3
Pd	5.50E+01	— ^a	SN0002KDVALUES.000, Table 1
Sn	1.30E+02	— ^a	SN0002KDVALUES.000, Table 1
Sb	4.50E+01	— ^a	SN0002KDVALUES.000, Table 1
I	1.00E+00	8.10E+01	SN0002KDVALUES.000, Table 3
Cs	2.80E+02	1.00E+04	SN0002KDVALUES.000, Table 3
Sm	2.45E+02	— ^a	SN0002KDVALUES.000, Table 1
Pb	2.70E+02	1.40E+03	SN0002KDVALUES.000, Table 3
Bi	1.00E+02	— ^a	SN0002KDVALUES.000, Table 1
Po	1.50E+02	7.02E+03	SN0002KDVALUES.000, Table 3
Ra	5.00E+02	2.10E+04	SN0002KDVALUES.000, Tables 1 & A-1
Ac	4.50E+02	— ^a	SN0002KDVALUES.000, Table 1
Th	3.20E+03	1.50E+05	SN0002KDVALUES.000, Table 3
Pa	5.50E+02	— ^a	SN0002KDVALUES.000, Table 1
U	3.50E+01	2.20E+03	SN0002KDVALUES.000, Table 3
Np	5.00E+00	3.90E+02	SN0002KDVALUES.000, Table 3
Pu	5.50E+02	3.60E+04	SN0002KDVALUES.000, Table 3
Am	1.90E+03	3.00E+05	SN0002KDVALUES.000, Table 3
Cm	4.00E+03	2.30E+04	SN0002KDVALUES.000, Table 3

NOTE: ^a Conservative Estimate Not Reported by Sheppard and Thibault (1990, Tables 1, 3, and A-1).

4.2 CRITERIA

There are no criteria that are directly applicable to the analyses addressed in this AMR. However, the NRC's Total System Performance Assessment and Integration (TSPA&I) Issue Resolution Status Report (IRSR) (NRC 1998) establishes generic technical acceptance criteria considered by the NRC staff to be essential to a defensible, transparent, and comprehensive assessment methodology for the repository system. These regulatory acceptance criteria address five fundamental elements of the U.S. Department of Energy's (DOE's) TSPA model for the Yucca Mountain site, namely:

1. Data justification (focusing on sufficiency of data to support the conceptual basis of the process model and abstractions)
2. Data uncertainty and verification (focusing on technical basis for bounding assumptions and statistical representations of uncertainties and parameter variabilities)
3. Data uncertainty (focusing on alternative data consistent with available site data)
4. Data verification (focusing on testing of model abstractions using detailed process-level models and empirical observations)
5. Integration (focusing on appropriate and consistent coupling of abstractions).

Relevant to the topic of this AMR, elements (1) through (4) of the acceptance criteria are addressed herein and/or in the supporting calculation document(s). Element (5) of the NRC acceptance criteria, which strictly applies to the completed synthesis of process-level models and abstractions, will be addressed separately in the TSPA-SR.

This AMR was prepared to comply with the above NRC TSPA&I acceptance criteria, as well as the DOE interim guidance (Dyer 1999).

4.3 CODES AND STANDARDS

This is not applicable to this report because there are no codes and standards that apply to the analyses addressed in this AMR.

5. ASSUMPTIONS

5.1 SURFACE SOIL EROSION ANALYSIS

It is assumed that soil erosion rates are accelerated in land subjected to use for agricultural and/or domestic purposes. Under natural conditions the rate of soil removal by erosion is generally in approximate equilibrium with the rate of soil formation from the transformation of underlying bedrock, alluvium, colluvium or other material constituting the parent material. Under these conditions the soil depth (or thickness) is maintained at a near constant depth (Troeh et al. 1980, p. 4). Anthropogenic activities, including tilling of cropland, removal of vegetation, and grazing of pasture or rangeland, typically tend to accelerate the natural rate of soil removal for a given environment. The disturbed soil is left with less protection against the detaching action of raindrop impact and the transporting action of runoff water and wind. Thus, the formation of

new soil cannot keep pace with the accelerated erosion rate and the soil material progressively becomes thinner until a new equilibrium is established or the soil material is removed entirely (Troeh et al. 1980, pp. 5-6). A general consequence of accelerated soil erosion is a decline in plant growth and productivity. Although production can at times be maintained with the addition of fertilizers or other costly management practices, the soil's natural production potential declines because the shallower soil has lower water storage capacity, reduced capacity to accommodate plant root growth, and lower fertility status than it did prior to accelerated erosion.

Soil that is continuously irrigated with radionuclide-contaminated water will experience a progressive increase in radioactivity if soil and associated radionuclides are not removed by erosion and leaching. However, soil erosion rates on agricultural land within the Amargosa Valley are accelerated to various degrees, with rates dependent upon the various land use patterns (types of crops grown) and management techniques practiced by the land owners. Therefore, to adequately assess the degree of build-up in radioactivity in soils subjected to continuous or repetitive irrigation with contaminated water, an estimate of concurrent soil loss by erosion is needed.

Over the past several decades, methods of evaluating the effectiveness of erosion control methods have developed with the desired objective of encouraging conservation practices that would reduce soil erosion losses to tolerable rates (Wischmeier and Smith 1978; Woodruff and Siddoway 1965; Yoder and Lown 1995). Tolerable soil loss rates (*T*-values) are defined as the maximum annual rates of soil erosion that will permit the indefinite maintenance of productivity (Troeh et al. 1980, pp. 147-150). Annual soil loss beyond the *T*-value will compromise long-term productivity because this may result in significant reduction in plant nutrients and gully formation and sedimentation may hamper tillage operations. Troeh et al. (1980, p. 149) identified the five levels of soil erosion tolerance established by the USDA Natural Resource Conservation Service (formerly the Soil Conservation Service) based upon the properties of the soils and their resiliency to productivity decline upon erosion; these annual soil erosion tolerance loss groups are equal to about 2, 5, 7, 9, and 11 t/ha. The maximum tolerable loss (11 t/ha/yr) is for deep, permeable, well-drained, productive soils. These soils can tolerate greater rates of surface soil loss and still sustain their productive nature. At the other end of the spectrum, the 2 t/ha/yr soil loss tolerance rate corresponds to shallow soils with unfavorable subsoils and parent materials that severely restrict root penetration and soil development to offset the surface soil losses; these soils cannot sustain even moderate rates of soil erosion and still maintain their productivity.

Guidance and assistance with the implementation of conservation practices are available to agricultural land users within the State of Nevada from the various county agricultural extension services and the USDA NRCS in an effort to curb annual soil losses through erosion. In particular, USDA-sponsored Soil and Water Conservation Districts were set up in each county, or portion of a county, across the United States, as a result of the Soil Conservation and Domestic Allotment Act of 1935, Public Law 74-46. The primary objective of these local Conservation Districts is to offer a broad program of assistance in soil and water conservation on the land and thereby foster the judicious use of land resources.

In this analysis, the *T*-value has been selected as a reasonable representation of the "worst-case" annual soil loss rate from Amargosa Valley land subjected to agricultural or other uses such as

domestic/recreational activities. This assumption is justified because the current practice in agricultural communities is to manage soil resources in such a manner as to sustain long-term productivity (USDA NRCS 1998) and therefore restrict annual erosion losses to levels well below the established *T*-values.

For the conservative bounding estimate, soil erosion is assumed to be impeded entirely (see Section 6.1.2). The assumption that there would be virtually no soil loss from agricultural land is entirely plausible, especially under conditions of perennial crop production (e.g., alfalfa). Under these conditions the soil surface is protected from erosion (wind and/or water erosion) throughout the calendar year by the continuous vegetation cover on the ground surface. A higher biological dose to the receptor would result under these circumstances (no surface soil removal) because the radionuclides introduced into the soils by surface irrigation would not be removed by surface processes and thereby pose a greater exposure risk to a receptor via the various exposure pathways (e.g., plant uptake and subsequent human ingestion, external exposure [ground shine], etc.). An exception is the direct groundwater ingestion pathway which is independent of soil processes.

In the case of analyzing selected events of volcanic ash deposits (i.e., thin deposits of ash) onto the land resources in the Amargosa Valley, the total radionuclide quantity associated with contaminated ash deposited on the ground surface will also be “depleted” annually at a rate commensurate with the annual rate of surface soil removal. This premise is based upon the assumption of complete mixing of thin deposits of ash within the surface soil layer by plowing. Under these conditions the soil erosion rates are thereby controlled by the erosiveness of the original soil, rather than the erosion characteristics of the ash material itself or some unknown admixture of soil and ash. In this abstraction, as well as in the base case wherein the radionuclides are deposited onto the existing Amargosa Valley soils by continuous or repetitive irrigation with contaminated water, radionuclide concentrations will be reduced annually in proportion to the annual reduction in the default 15-cm thick surface soil layer modeled by GENII-S.

5.2 LEACHING ANALYSIS

It is assumed that soil/liquid partition coefficients, K_d values, recommended for sandy textured soils are appropriate for calculating leaching coefficients for the soils in the vicinity of Lathrop Wells. The K_d values selected as input parameters for calculations of radionuclide-specific leaching coefficients are taken from Sheppard and Thibault (1990, Tables 1, 3, and A-1). These data are qualified (i.e., values were considered as “accepted data” by the YMP Office of Project Execution, OPE). The values are recommended by Sheppard and Thibault (1990, Tables 1, 3, and A-1) for sandy soils (sandy loams, loamy sands, gravelly and/or cobbly sandy loams and loamy sands) which are the types of soils found in Amargosa Valley (CRWMS M&O 1999d, Appendix C). LaPlante and Poor (1997, p. 2-22) also used these values for their calculations of leaching coefficients in a 1997 evaluation of site-specific characteristics and parameters for modeling environmental pathways of radionuclide transport in the vicinity of Yucca Mountain.

While it has been shown by some researchers (Griffin and Shimp 1976) that pH is an important factor affecting K_d , references were not found that show the effect of pH on K_d values specific for sandy soils. Griffin and Shimp (1976) looked at the effects of pH on adsorption of Pb, but this study was on pure clay minerals. Incorporated into this analysis is the range of K_d values reported by Sheppard and Thibault (1990, Tables 1, 3, and A-1). The upper range of the K_d values recommended for sandy-textured soils likely corresponds to soils with alkaline pH, similar to the soils in the Amargosa Valley. These K_d values could be different from other values used in TSPA-VA for the unsaturated zone (UZ) (CRWMS M&O 1998b, Table 7-3, p. T7-26) and saturated zone (SZ) transport calculations (CRWMS M&O 1998c, Table 8-19, pp. T8-22). However, a major reason for this difference is that, in contrast to the volcanic rock and alluvial valley fill sediments considered in the UZ/SZ transport calculations, this analysis was focused on biologically-active surface soils.

The values selected for the precipitation (P), irrigation (I), and evapotranspiration (E) parameters (see Table 2) are those associated with the hay and forage biosphere plant group, specifically alfalfa.

The GENII-S default value of 15 cm (Napier et al. 1988, p. 4.58) was employed as the soil depth (D) input parameter value. The value of 1.50 g/cm³ was selected as the soil bulk density (ρ) because this is the computed mean value for all the soils considered in this analysis (see Table 2). It is assumed that although radionuclides can be leached below this surface soil layer, the radionuclides will not reach the underlying groundwater aquifer in the Amargosa Valley through this process. This assumption is justified because under these arid conditions, the cumulative water input (total annual precipitation and irrigation water) is not sufficient to leach constituents in the soil much beyond the designated 15 cm surface soil depth.

Volumetric water content (θ) at field capacity is not a routine analysis in standard USDA soil survey procedures and therefore these data were not available for the major soil series considered in this analysis. Field capacity water content is defined as the water content remaining in soils after complete saturation (such would occur after flood irrigation or prolonged heavy precipitation) and at the time that all free drainage has ceased (Brady 1984, p. 97). After all free drainage has occurred, the soil micropores or capillary pores remain filled with water, but water in the macropores has moved to lower depths because of gravitational forces. Napier et al. (1988, p. 4.58) used a volumetric water content estimate near field capacity for the calculation of leaching coefficients, however, his value for field capacity water content was likely equal to the soil's total porosity (≈ 0.5) and, thus, probably calculated under the assumption that all soil pores are interstitially connected and potentially available for water occupation. However, discontinuities in pore channels exist in natural soils and generally not all pore space is filled with water at the field capacity index level. Consequently, a volumetric water content value smaller than that used by Napier et al. (1988, p. 4.58) is probably more appropriate for this analysis.

Baes and Sharp (1983, p. 20, Table 2) reported the results of an analysis of volumetric water contents at field capacity and wilting point for 154 pasture and cropland soils. The values they recommended for volumetric water content at field capacity were 0.345 ml/cm³, 0.360 ml/cm³, 0.319 ml/cm³, and 0.217 ml/cm³, for silt loams, clays/clay loams, loams, and sandy loams,

respectively. Therefore, the value (0.217 ml/cm³) recommended by Baes and Sharp (1983) is considered to be appropriate for the volumetric water retention capacity at field capacity for the soils considered in this analysis and was used as the volumetric water content (θ) input parameter.

6. ANALYSES/MODEL

6.1 SOIL EROSION ANALYSIS

6.1.1 Reasonable Representation Case Analyses

As discussed in Section 5.1, the USDA-established soil-loss tolerance index, T -value, is considered to be a sound, reasonable, and defensible representation of the maximum annual quantity of soil loss that would potentially occur in the Amargosa Valley area, now and in the future, if current institutional controls (e.g., USDA and State/County Agricultural Extension Service guidance and support for land use management) remain in place.

The annual soil depth reduction corresponding to T -values for each of the major soil series occurring in the vicinity of Lathrop Wells is calculated by multiplying the annual soil mass loss rate corresponding to the soil's T -value by the reciprocal of soil bulk density (ρ)

$$\begin{aligned} \text{Arizo Soil} - T &= 11.21 \text{ t/ha/yr} \\ \rho &= 1.40 \text{ g/cm}^3 \text{ or } 1.40 \times 10^{-6} \text{ t/cm}^3 \end{aligned}$$

The annual soil depth reduction for this soil is:

$$11.21 \text{ t/ha/yr} \times \frac{1.0 \text{ cm}^3}{1.4 \times 10^{-6} \text{ t}} \times \frac{1 \text{ m}^2}{10,000 \text{ cm}^2} \times \frac{1.0 \text{ ha}}{10,000 \text{ m}^2} = 0.08 \text{ cm/yr}$$

The annual soil depth reduction corresponding to soil T -values for those soil series occurring in the vicinity of Lathrop Wells ranged from a low of 0.026 cm/yr for the Shamock series with a bulk density of 1.70 g/cm³ to a high of 0.080 cm/yr¹ for the Arizo, Commski, Sanwell, and Yermo soils with a bulk densities of 1.40 g/cm³ (Table 4). However, the calculated annual soil depth reduction rates are generally between 0.06 and 0.08 cm/yr, with the exception of the Shamock series, is a moderately deep, gravelly-fine sandy loam soil (CRWMS M&O 1999d, Appendix C) and is less tolerable of soil erosion than the other deeper soils before experiencing a reduction in productivity.

Table 4. Calculated Best Estimate Annual Soil Depth Reductions for the Soils in the Vicinity of Lathrop Wells, Amargosa Valley

Soil Series	T Value (t/ha/yr)	Bulk Density (ρ) (g/cm ³)		Annual Soil Depth Reduction (cm/yr)	
		Lower Range	Upper Range	Lower Bulk Density Estimate	Upper Bulk Density Estimate
Arizo	11.21	1.40	1.55	0.080	0.072
Commski	11.21	1.40	1.60	0.080	0.070
Corbilt	8.97	1.35	1.50	0.066	0.060
Sanwell	11.21	1.40	1.60	0.080	0.070
Shamock	4.48	1.50	1.70	0.030	0.026
Yermo	11.21	1.40	1.60	0.080	0.070

6.1.2 Conservative Bounding Estimate Analysis

The conservative bounding estimate analysis assumes that erosion would be eliminated altogether and thus, no annual soil depth reductions would occur for any of the above soils. The scenario (i.e., zero soil erosion losses) is considered to be conservative because these conditions would result in the maximum radiation dose to the receptor. From a realistic standpoint, the scenario is entirely plausible on those land areas under optimum management because wind and water erosion are virtually suppressed completely under conditions of perennial vegetation cover (e.g., alfalfa fields) on nearly level to level terrain such is characteristic of much of the agricultural land within the Amargosa Valley.

6.2 LEACHING ANALYSIS

The residence time of radionuclide contaminants in soils can have a large influence on the relative contribution of the various contaminant exposure pathways to a receptor's total exposure. Therefore, assessment of health risks to humans from radionuclide-contaminated soils must take into account the removal of radionuclides from the surface soil to the underlying strata by leaching. Radionuclides removed from the modeled soil layer by leaching (similarly to those depleted by surface soil removal), are no longer available for many of the possible exposure pathways including plant uptake, inhalation and ingestion of surface soil. The GENII-S code used in the TSPA for the proposed Yucca Mountain repository uses element-specific loss terms that account for removal of contamination from surface soils through leaching into deeper layers.

Equation 1 uses the relationship from Baes and Sharp (1983, p. 18) to calculate the leaching coefficients, λ (yr^{-1})

$$\lambda = \frac{P + I - E}{D \times \theta \times (1.0 + \rho / \theta \times K_d)} \quad (\text{Eq. 1})$$

where:

P , I , and E are the annual precipitation, irrigation, and evapotranspiration rates [cm/yr]

D = Depth of surface soil – default value [15 cm]

θ = Volumetric water content of soil – assumed value [0.217 ml/cm^3 or cm^3/cm^3]

ρ = Surface soil bulk density [g/cm^3]

K_d = Surface soil solid/liquid partition coefficient, K_d , for a specific radionuclide (isotope independent) and soil type [L/kg or cm^3/g]

[Note that for the volumetric water (θ) parameter, the units ml and cm^3 are equivalent and for the K_d parameter the units L/kg and cm^3/g are equivalent.]

The parameter with the most variability and, potentially, the largest effect on the calculated leaching coefficients is the soil solid/liquid partition coefficient (K_d). However, an extensive review of the existing soil information specific to Nye County, Nevada, and more importantly, specific to the Amargosa Valley, revealed that soil data were collected chiefly for agricultural purposes and did not include values for soil solid/liquid partition coefficients. Therefore, values recommended for sandy-textured soils by Sheppard and Thibault (1990, Tables 1, 3, and A-1) were used for the analysis because they correspond to soils with sandy loam textures which are the dominant soil textural classes found in the Amargosa Valley (CRWMS M&O 1999d, Appendix C). LaPlante and Poor (1997, p. 2-22) used the same values for their calculations of leaching coefficients in a 1997 evaluation of site-specific characteristics and parameters for modeling environmental pathways of radionuclide transport in the vicinity of Yucca Mountain.

The soils in the Amargosa Valley are alkaline ($\text{pH} > 7.0$) (CRWMS M&O 1999d) and some researchers have shown that pH may be an important factor affecting K_d values (Brady et al. 1998; Gee et al. 1983; Griffin and Shimp 1976; Nakayama et al. 1988; Sheppard 1985; Sheppard and Thibault 1990). However, data from studies that investigated the effect(s) of pH on K_d values for soils present in the Amargosa Valley, or even for sandy soils in general, were not successfully located. As stated previously (Section 5.2), Griffin and Shimp (1976) did evaluate the effects of pH on adsorption of Pb, but this study was on pure clay minerals. However, many of the radionuclides that would potentially be introduced into the soil through irrigation with contaminated water are metallic in nature and it is well documented that metal solubility in soils is greatly reduced with increasing pH (Bohn et al. 1979, pp. 212-213; Brady et al. 1998, p. 78; Tisdale et al. 1985, p.512; Coughtrey and Thorne 1983, Volume 2, p. 96 and p. 219). Therefore, the upper range of K_d values recommended by Sheppard and Thibault (1990) for sandy-textured soils are considered appropriate for the alkaline Amargosa Valley soils included in this analysis.

Example Calculation–Leaching Coefficient for Plutonium (Pu)

Using Equation 1, the general soil input parameter values listed in Table 2, and the soil solid/liquid partition coefficient (K_d) for Pu listed in Table 3, the leaching coefficients (λ) are calculated with the use of a FORTRAN 77 routine (MOL.19991011.0124, software routine verification documentation; MOL.19991011.0125, routine's source code listing) as follows:

Best Estimate Leaching Coefficient:

$$\lambda = \frac{10.24 + 240.44 - 235.43}{15 \times 0.217 \times (1.0 + 1.5 / 0.217 \times 550)} = 1.23 \times 10^{-3}$$

Conservative Bounding Estimate Leaching Coefficient:

$$\lambda = \frac{10.24 + 240.44 - 235.43}{15 \times 0.217 \times (1.0 + 1.5 / 0.217 \times 36000)} = 1.88 \times 10^{-5}$$

The leaching coefficients calculated for the reasonable representation case (Best Estimate) and the conservative bounding estimate (Conservative Estimate) for the 27 radionuclide elements considered in this analysis are listed in Table 5.

With the exception of molybdenum (Mo), there is a difference of either one or two orders of magnitude between the two leaching coefficient estimates for the radionuclide elements evaluated, with the Best Estimate values being greater. As mentioned previously, the conservative K_d values (Table 3) were selected to represent the conservative bounding estimate for the non-disruptive (base case) PA biosphere analysis. The resulting smaller leaching coefficients are consistent with the conservative bounding assertion because the lower the degree of radionuclide leaching from the surface soil, the greater the potential for exposure to the receptor through the radionuclide transfer pathways modeled by GENII-S. One exception is the well water consumption pathway because, as modeled in the base case performance assessment, the radionuclide content in groundwater is due entirely from the direct transfer of radionuclides in the source waste within the repository by SZ flow and transport and is therefore independent of radionuclide leaching from topsoil.

Major differences in the leaching coefficients among the various radionuclide elements are mostly due to differences in the chemical nature of the elements and their subsequent stable oxidation states. For example, the large leaching coefficient for technetium (Tc) reflects the element's propensity to exist in the +7 valence form and as the pertechnetate ion (TcO_4^-) in oxidized soil environments (Coughtrey and Thorne 1983, Vol. 3, p. 210). In this anionic form, Tc sorption by soil colloids is virtually non-existent and the radionuclide can readily be removed by leaching, much like the nitrate-nitrogen ion (NO_3^-). On the other hand, for most of the metallic elements, the calculated low leaching coefficients reflect the tendency of these elements to bind strongly onto negatively-charged soil surfaces, sometimes irreversibly (Brady et al. 1998,

pp. 61-64). Additionally, many of these elements readily form carbonate mineral phases and/or become trace constituents in CaCO_3 precipitates under alkaline soil conditions (Brady et al. 1998, p. 47).

Table 5. Leaching Coefficients (λ) Calculated for 27 Radionuclide Elements (Isotope Independent). *Best Estimate* and *Conservative Estimate* Values Represent the Reasonable Representation and Conservative Bounding Estimate, Respectively

Element	Leaching Coefficient, λ , (yr^{-1})	
	Best Estimate	Conservative Estimate
C	1.32E-01	9.35E-02
Ni	1.69E-03	1.88E-04
Se	1.23E-02	9.66E-03
Sr	4.47E-02	3.56E-03
Y	3.98E-03	— ^a
Mo	6.68E-02	1.30E-02
Zr	1.13E-03	— ^a
Nb	4.23E-03	— ^a
Tc	2.77E+00	4.20E-02
Pd	1.23E-02	— ^a
Sn	5.20E-03	— ^a
Sb	1.50E-02	— ^a
I	5.92E-01	8.35E-03
Cs	2.42E-03	6.77E-05
Sm	2.76E-03	— ^a
Pb	2.51E-03	4.84E-04
Bi	6.76E-03	— ^a
Po	4.51E-03	9.65E-05
Ra	1.35E-03	3.23E-05
Ac	1.50E-03	— ^a
Th	2.12E-04	4.52E-06
Pa	1.23E-03	— ^a
U	1.93E-02	3.08E-04
Np	1.32E-01	1.74E-03
Pu	1.23E-03	1.88E-05
Am	3.56E-04	2.26E-06
Cm	1.69E-04	2.94E-05

NOTE: ^a Conservative Estimate was not calculated because an applicable K_d value was not provided by Sheppard and Thibault (1990, Tables 1, 3, and A-1). Although zero could be used as the conservative value, this might be unreasonably conservative and unrealistic in many cases (e.g., elements with high leaching coefficients). Therefore it is recommended that the best estimate be used as the conservative value for those radionuclide elements that do not have a Conservative Estimate listed in Column 3 above.

6.3 EXPECTED SOURCES OF UNCERTAINTY AND APPLICATION TO PA ANALYSIS

Because the analyses of annual soil depth reduction rates were deterministic in nature, i.e., based upon reasonable maximum soil erosion rates associated with current land use practices, the major source of uncertainty in the analysis is the assumption that these current management and

conservation practices will continue into the future. Land resources in the Amargosa Valley could be used and managed in a variety of ways. However, as discussed previously (Section 5.1), technical guidance and assistance is currently provided to land owners/managers through local USDA-sponsored Conservation Districts with the objective of fostering land use practices that will result in sustained productivity. Maintaining annual soil erosion losses below the levels prescribed by the established soil loss tolerance factor (T -value) is a major focus of this program. If current institutional services such as the Southern Nye County Conservation District guidance and assistance to land owners/managers in the Amargosa Valley are abandoned, present land use practices could deviate to other less conservation-oriented uses. For example, some of the land currently used for alfalfa production could be taken out of agricultural production and used for other purposes such as urban development. Under these circumstances, and especially during the transitional periods when the land has been graded for development but the development has not occurred, annual soil losses exceeding the USDA established T -value levels could occur.

Another potential source of uncertainty in the soil depth reduction calculations is related to uncertainty in actual soil bulk density values in the area in which the critical group would reside. For the soil series evaluated, a range between an upper and lower bulk density bounding value were provided (Table 1). Calculated annual depth reduction rates between the upper and lower bulk density values provided for each soil series differed only between 10 to 13 percent (Table 4). Compared to the potential effects of the uncertainty associated with the changes in annual erosion rates that could potentially result from land use or management changes, uncertainty in the calculations arising from soil bulk density variation within soil series is relatively minor.

The largest degree of uncertainty in the leaching coefficient calculations is associated with the K_d values selected for each radionuclide, hence the leaching coefficient calculations are most sensitive to these input parameters (exceptions may occur when the element K_d is small (≤ 1)). Published information on radionuclide-specific K_d measurements for soils in the Amargosa Valley was not found, and, potentially, there is a degree of uncertainty in how the values used in the calculations in Table 3 would differ from values obtained from actual experimental analysis on the six Amargosa Valley soil series considered in the analysis.

7. SUMMARY AND CONCLUSIONS

The analyses reported in this AMR were conducted to address the potential impact(s) of erosion and leaching as they relate to the accumulation/removal of radionuclides in soils. The results of this study will be used in subsequent AMR analyses to determine the total annual build-up of radionuclides resulting from irrigation with contaminated groundwater and the potential removal rate of radionuclides in contaminated ash deposits within the Amargosa Valley. To assess radionuclide build-up in soils subjected to continuous or repetitive irrigation with contaminated water, an estimate of concurrent soil loss by erosion is needed. Although the GENII-S code used in the TSPA biosphere analysis considers the leaching process in its calculations, the objective of this analysis of soil/liquid partition coefficients was to derive values that are more appropriate for the soil environment in the Amargosa Valley.

The estimates of annual soil depth reduction (Table 4) are applicable for use in calculations of net cumulative radionuclide build-up as a result of irrigation on arable land with contaminated groundwater, as well as for assessing the removal of radionuclide-contaminated ash deposited on these lands. In the former case, the radionuclide content removed annually by surface soil

erosion will be subtracted from the annual irrigation input of radionuclides. In the latter case, the total radionuclide quantity associated with contaminated ash deposited on the ground surface will be “depleted” annually at a rate commensurate with the annual rate of surface soil removal. This second scenario is based on the assumption that thin deposits of ash within the surface soil layer are completely mixed within the original surface soil layer, with subsequent erosion rates controlled by the erosion characteristics of the original soil, rather than the erosion characteristics of the ash material itself or some unknown admixture of soil and ash. The radionuclide concentrations in the soils will be reduced in proportion to the annual soil depth reduction estimates (Table 4) from the default 15-cm thick surface soil layer modeled by GENII-S for both of the above abstractions.

Two values were calculated for the surface soil erosion loss estimates and the leaching coefficients: 1) a reasonable estimate based on the soil properties in the Amargosa Valley and the land use characteristics of the critical group proposed by the NRC, and 2) a conservative, high dose-yielding bounding value calculated under the conditions that, potentially, would result in higher exposure rates (i.e., the conservative bounding estimate).

The USDA-established soil loss tolerance value (T), designated as the upper limit of annual surface soil loss beyond which long-term productivity is compromised, was selected as the reasonable and defensible maximum annual quantity of soil removal by erosion that, potentially, would occur in the Amargosa Valley area. This is based upon the assumption that the current USDA and State/County Agricultural Extension Service guidance and support for land use management remain in place.

The annual soil depth reduction estimates (Table 4) for the soils occurring in the vicinity of Lathrop Wells ranged from a low of 0.026 cm/yr for the Shamock series with a bulk density of 1.70 g/cm³ to a high of 0.080 cm/yr for the Arizo, Commski, Sanwell, and Yermo soils with bulk densities of 1.40 g/cm³. However, with the exception of the Shamock series, which is a moderately deep, gravelly fine sandy loam soil and therefore less resilient to soil erosion before experiencing a reduction in productivity, the calculated annual soil depth reduction rates are generally between 0.06 and 0.08 cm/yr. For the conservative bounding estimate, soil erosion was assumed to be checked entirely (i.e., no surface soil erosion loss).

The leaching coefficient calculations are most sensitive to the K_d input parameter, with the magnitude of the leaching coefficients being inversely related to the magnitude of element's respective K_d . A major objective of the analysis was to attempt to use site-specific soil data, including K_d values, preferably obtained from studies on soils present in the vicinity of Yucca Mountain. However, in the absence of such data, values recommended for sandy-textured soils by Sheppard and Thibault (1990, Tables 1, 3, and A-1) were chosen for the analysis. These values are deemed to be the most appropriate and comprehensive data available. Other input parameter values including soil bulk density, precipitation, evaporation, and irrigation rate, were based upon data obtained from the Amargosa Valley.

The leaching coefficients (Table 5) calculated with the best estimate soil/liquid partition coefficient (K_d) were generally larger, by either one or two orders of magnitude, than those calculated with the conservative K_d estimates. Differences in the leaching coefficients among the various radionuclide elements were largely due to differences in their chemical nature and their subsequent stable oxidation states. For most of the metallic and metallic-like elements (e.g., Am, Ni, Sm, Pu, U), low leaching coefficients were attributed to strong binding by negatively-

charged soil surfaces (i.e., high K_d). On the other hand, the large leaching coefficient calculated for Tc resulted from the element's low K_d , reflecting the element's propensity to exist as an anion in aerobic soils, and thus exhibit low adsorption to negatively charged mineral colloids in oxidized soil environments.

It is interesting to note that those elements that are most likely to reach the accessible environment, (where exposure occurs), via the groundwater pathway, are also the most rapidly leached from the (agricultural) soil and are consequently less available for crop/animal uptake and subsequent consumption by humans. This is important because Tc and I, which both have relatively small K_d values are, from the standpoint of migration from the repository to the biosphere, two of the largest potential dose contributors in the 10,000 year regulatory time frame. Consequently, uncertainty in the K_d values (for the soils in Amargosa Valley) of these two elements could significantly impact dose calculations and perhaps the margin of regulatory compliance.

For the conservative bounding estimate, the use of the largest K_d value recommended for each radionuclide element by Sheppard and Thibault (1990, Tables 1, 3, and A-1) generally produced a considerably smaller leaching factor, particularly where the maximal (conservative estimate) K_d was substantially much larger than the "best estimate" K_d . For exposure through the food chain pathways (via soil), the potential dose from metallic elements such as neptunium (Np), plutonium (Pu), and others is increased, perhaps significantly, because of their retention in the surface soil. Of course, since the resulting soil concentrations of these elements are relatively greater for this case, the dose risk due to direct external (ground shine) and inhalation exposure pathways will be increased. However, the TSPA-VA performance assessment (CRWMS M&O, 1998a) showed that ground shine and inhalation contribute a very small fraction of the total dose due to all pathways.

The TSPA-VA analyses did not consider soil build-up, but this process is included in the TSPA-SR. Thus, the conservative bounding estimate analyses conducted for this AMR will make the PA analysis more comprehensive because they are a necessary component of the soil buildup abstraction.

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8.3 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

MO9903CLIMATOL.001. Climatological Tables From 1986-1997 Meteorological Data From Site 1 Through Site 9 EFPD Meteorological Sites. Submittal date: 03/23/1999.

MO9912MWDEEA06.003. Evapotranspiration Estimates for Alfalfa in the Reference Biosphere. Submittal date: 12/14/1999.

MO9912SPAING06.033. Ingestion Exposure Pathway Parameters. Submittal date: 12/22/1999.

SN9912USDASOIL.000. U.S. Department of Agriculture (USDA) Soil Survey Data – Lathrop Wells. Submittal date: 12/20/99.

SN0002KDVALUES.000 Soil/Liquid Partition Coefficients, K_d values. Submittal Date: 02/10/00.

ATTACHMENT I – DOCUMENT INPUT REFERENCE SYSTEM (DIRS)

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SHEET

1. Document Identifier No./Rev.: ANL-NBS-MD-000009 REV 00		Change:	Title: Evaluate Soil/Radionuclide Removal by Erosion and Leaching						
Input Document		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
2a	Baes, C.F., III and Sharp, R.D. 1983. "A Proposal for Estimation of Soil Leaching and Leaching Constants for Use in Assessment Models." <i>Journal of Environmental Quality</i> , 12 (1), 17-28. Madison, Wisconsin: Published Cooperatively by American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. TIC: 245676.	Page 18 Table 2, p. 20	N/A; Reference Only	5.2, 6.2	Equation for calculating leaching coefficients. Assumed estimate of volumetric water content parameter used in leaching coefficient equation.	N/A	N/A	N/A	N/A
1									
2	Bohn, H.L.; McNeal B.L.; and O'Connor, G.A. 1979. <i>Soil Chemistry</i> . New York, New York: John Wiley & Sons. TIC: 245713.	Pages 212-213	N/A; Reference Only	6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
3	Brady, N.C. 1984. <i>The Nature and Property of Soils</i> . 9 th Edition. New York, New York: Macmillan Publishing Co. Library tracking number: 238332C.	Page 434 Page 97	N/A; Reference Only	4.1.1 5.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
4	Brady, P.V.; Brady, M.V; and Borns, D.J. 1998. <i>Natural Attenuation: CERCLA, RBCA's, and the Future of Environmental Remediation</i> . Boca Raton, Florida: Lewis Publishers. TIC: 245714	Pages 47, 61-64, 78	N/A; Reference Only	6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
5	Coughtrey, P.J. and Thorne, M.C. 1983. <i>Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems – A Critical Review of Data</i> . EUR 8115. Rotterdam, The Netherlands: A.A. Balkema. TIC: 240299.	Volume 2 pages 96, 219; Volume 3 page 210	N/A; Reference Only	6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SHEET

1. Document Identifier No./Rev.: ANL-NBS-MD-000009 REV 00			Change:		Title: Evaluate Soil/Radionuclide Removal by Erosion and Leaching					
Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To			
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed	
6	CRWMS M&O. 1998. <i>Total System Performance Assessment–Viability Assessment (TSPA-VA) Analyses Technical Basis Document. Chapter 9 Biosphere.</i> B00000000-01717-4301-00009, Rev 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0009.		N/A; Reference Only	1 7	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A	
7	CRWMS M&O. 1998. <i>Total System Performance Assessment–Viability Assessment (TSPA-VA) Analyses Technical Basis Document. Chapter 7 Unsaturated Zone Radionuclide Transport.</i> B00000000-01717-4301-00007 Rev 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0007.		N/A; Reference Only	5.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A	
8	CRWMS M&O. 1998. <i>Total System Performance Assessment–Viability Assessment (TSPA-VA) Analyses Technical Basis Document. Chapter 8 Saturated Zone Flow and Transport.</i> B00000000-01717-4301-00008 Rev 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0008.		N/A; Reference Only	5.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A	
9	CRWMS M&O. 1999. <i>Status of the Radionuclide Screening for the TSPA-SR.</i> Input Transmittal R&E-PA-99217.Ta. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990719.0182.		N/A; Reference Only	1	Reference of other project analysis used as basis for selection of radionuclide elements to included in the leaching coefficient calculations.	N/A	N/A	N/A	N/A	
10	CRWMS M&O. 1999c. <i>Conduct of Performance Assessment.</i> Activity Evaluation. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991028.0092.		N/A; Reference Only	2.0	General reference to activity evaluation.	N/A	N/A	N/A	N/A	

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed
11	CRWMS M&O. 1999. <i>Evaluate Soil/Radionuclide Removal by Erosion and Leaching Rev. 00</i> . TDP-NBS-MD-000006. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991209.0197.	All	N/A; Reference Only	1	Development Plan describing work to be conducted under this AMR analysis.	N/A	N/A	N/A	N/A
12	CRWMS M&O. 1999. <i>Evaluation of Soils in the Northern Amargosa Valley</i> . B00000000-01717-5705-00084 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990224.0268.	Figure 1 pages 2-3 Appendix C	N/A; Reference Only	4.1.1, 6.1.1 4.1.2, 5.2, 6.2	Soil survey information describing the soils to be considered in the analysis. Appendix C – soil series descriptions.	N/A	N/A	N/A	N/A
13	DOE (U.S. Department of Energy) 2000. <i>Quality Assurance Requirements and Description</i> . DOE/RW-0333P, Rev. 9. Washington D.C.: DOE OCRWM. ACC: MOL.19991028.0012.	All	N/A; Reference Only	2.0	Reference to Quality Assurance Requirements and Description	N/A	N/A	N/A	N/A
14	Dyer, J. R. 1999. "Revised Interim Guidance Pending Issuance of New U. S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." Letter from J. R. Dyer (DOE) to D. R. Wilkins (CRWMS M&O), September 9, 1999, OL&RC:SB-1714, with enclosure, "Interim Guidance Pending Issuance of New U. S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01)". ACC: MOL.19990910.0079.	All	N/A; Mgmt Edict/TDL	1.0 4.2	General reference to provide guidance on use of proposed rule 10 CFR Part 63.	N/A	N/A	N/A	N/A
15	Gee, G.W.; Rai, D.; and Serne, R.J. 1983. "Mobility of Radionuclides in Soil." <i>Chemical Mobility and Reactivity in Soil Systems</i> . SSSA Special Publication Number 11, 203-227. Madison, Wisconsin: Soil Science Society of America: American Society of Agronomy. TIC: 229832. Copyright Granted	All	N/A; Reference Only	6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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1. Document Identifier No./Rev.: ANL-NBS-MD-000009 REV 00		Change:	Title: Evaluate Soil/Radionuclide Removal by Erosion and Leaching						
Input Document		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
16	Golder. 1998. <i>RIP Integrated Probabilistic Simulator for Environmental Systems. Theory Manual and User's Guide</i> . November 1998. Redmond, Washington: Golder Associates Inc. TIC: 238560.	All	N/A; Reference Only	1	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
17	Griffin, R.A. and Shimp, N.F. 1976. "Effect of pH on Exchange-Adsorption or Precipitation of Lead from Landfill Leachates by Clay Minerals." <i>Environmental Science and Technology</i> , 10(13), 1256-1261. Washington, D.C.: American Chemical Society. TIC: 246051. Copyright Granted	All	N/A; Reference Only	5.2, 6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
18	LaPlante, P.A. and Poor, K. 1997. <i>Information and Analyses to Support Selection of Critical Groups and Reference Biospheres for Yucca Mountain Exposure Scenarios</i> . CNWRA 97-009. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. TIC: 236454.	Page 2-22	N/A; Reference Only	5.2, 6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
19	Leigh, C.D.; Thompson, B.M.; Campbell, J.E.; Longsine, D.E.; Kennedy, R.A.; and Napier, B.A. 1993. <i>User's Guide for GENII-S: A Code for Statistical and Deterministic Simulations of Radiation Doses to Humans from Radionuclides in the Environment</i> . SAND91-0561. Albuquerque, New Mexico: Sandia National Laboratories. TIC: 231133.	All	N/A; Reference Only	1	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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1. Document Identifier No./Rev.: ANL-NBS-MD-000009 REV 00		Change:	Title: Evaluate Soil/Radionuclide Removal by Erosion and Leaching						
Input Document		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
20	MO9903CLIMATOL.001. Climatological Tables From 1986-1997 Meterological Data From Site 1 Through Site 9 EFPD Meteorolgical Sites. Submittal date: 03/23/1999.	All	N/A; Qualified-VL2	4.1.2	Annual precipitation value for Lathrop Wells	N/A	N/A	N/A	N/A
21	MO9912MWDEEA06.003. Evapotranspiration Estimates for Alfalfa in the Reference Biosphere. Submittal date: 12/14/1999.	All	N/A; Technical Product Output	4.1.2	Annual evapotranspiration rate value for alfalfa production in Amargosa Valley	1	X	N/A	N/A
22	MO9912SPAING06.033. Ingestion Exposure Pathway Parameters. Submittal date: 12/22/1999.	All	TBV-3958	4.1.2	Irrigation rate for alfalfa production in Amargosa Valley	1	X	N/A	N/A
23	McCurley, R. 1999. Documentation of SOILMODEL program to calculate leaching factors Memo ACC: MOL.19991011.0125.	All	N/A, Reference Only	3.0	Description of SOILMODEL program (FORTRAN 77) that calculates radionuclide-specific leaching coefficients	N/A	N/A	N/A	N/A
24	McCurley, R. 1999. SOIL MODEL version A1.20 Software Routine Verification, Documentation of SOIL MODEL Program to Calculate Leaching Factors Memo ACC: MOL.19991011.0124.	All	N/A, Reference Only	3.0	Software routine verification documentation for calculation of leaching coefficients	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
25	Nakayama, S.; Arimoto, H.; Yamada, N.; Moriyama, H.; and Higashi, K. 1988. "Column Experiments on Migration Behaviour of Neptunium(V)." <i>Radiochimica Acta</i> , 44/45, 179-182. Munich: R. Oldenbourg Verlag; New York, New York: Academic Press. TIC: 246055.	All	N/A; Reference Only	6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
26	Napier, B.A.; Peloquin, R.A.; Strenge, D.L.; and Ramsdell, J.V. 1988. <i>Conceptual Representation. Volume 1 of GENII: The Hanford Environmental Radiation Dosimetry Software System</i> . PNL-6584. Richland, Washington: Pacific Northwest Laboratory. TIC: 206898.	Page 4.58	N/A; Reference Only	5.2	In section 5.2, general reference to provide background and scientific information to report and the default soil depth parameter (D).	N/A	N/A	N/A	N/A
27	NRC (U.S. Nuclear Regulatory Commission). 1998. <i>Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration</i> . Revision 1. Washington, D.C.: Division of Waste Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission. ACC: MOL.19990105.0083.	All	N/A; Reference Only	4.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
28	SN0002KDVALUES.000. Soil Solid/Liquid Partition Coefficients, Kd Values. Submittal Date: 02/10/00. URN-0010	Tables 1, 3, and A-1, values for sandy soils.	N/A; Accepted Data – AMOPE Approved	4.1.2	Soil solid/liquid partition coefficients, K _d values for Amargosa Valley Soils	N/A	N/A	N/A	N/A
29	SN9912USDASOIL.000. U.S. Department of Agriculture (USDA) Soil Survey Data – Lathrop Wells. Submittal date: 12/20/99.	Soil Loss Tolerance Values, Soil Bulk Density Values	N/A; Accepted Data – AMOPE Approved	4.1.1 4.1.2	Data source – input parameter values used for calculating annual soil loss estimates.	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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1. Document Identifier No./Rev.: ANL-NBS-MD-000009 REV 00		Change:	Title: Evaluate Soil/Radionuclide Removal by Erosion and Leaching						
Input Document		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
30	Sheppard, M. I. 1985. "Radionuclide Partitioning Coefficients in Soils and Plants and Their Correlation." <i>Health Physics</i> , 49, (1), 106-111. Baltimore, Maryland: Lippincott Williams & Wilkins. TIC: 246136.	All	N/A , Reference Only	6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
31	Sheppard, M.I. and Thibault, D.H. 1990. "Default Soil Solid/Liquid Partition Coefficients, K_d s, for Four Major Soil Types: A Compendium." <i>Health Physics</i> , 59(4), 471-482. New York, New York: Pergamon Press. TIC: 245952	Tables 1, 3, and A-1	N/A; Reference Only	4.1.2 5.2 6.2 7	General reference to recommended soil/liquid partition coefficients (K_d values) for use in leaching coefficient calculations.	N/A	N/A	N/A	N/A
32	Tisdale, S.L.; Nelson, W.L.; and Beaton, J.D. 1985. <i>Soil Fertility and Fertilizers. 4th Edition</i> . New York, New York: Macmillan Publishing Co. TIC: 240775.	Pages 4-6, 147-150, 512, 634	N/A; Reference Only	6.2	General reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
33	Troeh, F.R.; Hobbs, J.A.; and Donahue, R.L. 1980. <i>Soil and Water Conservation for Productivity and Environmental Protection</i> . Englewood Cliffs, New Jersey: Prentice-Hall. TIC: 246612.	Page 149 Pages 4-6, 147-150	N/A; Reference Only	4.1.1 5.1	General Reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
34	USDA (U.S. Department of Agriculture) Natural Resource Conservation Service. 1998. <i>Achieving Effective Land Stewardship: A Framework for Action</i> . Washington, D.C.: U.S. Department of Agriculture. TIC: 246168.	All	N/A; Reference Only	5.1	General Reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
35	Wischmeier, W.H. and Smith, D.D. 1978. <i>Predicting Rainfall Erosion Losses—A Guide to Conservation Planning, Agriculture Handbook Number 537</i> , 58 pp. Washington, D.C.: Department of Agriculture, Science and Education Administration. TIC: 245752.	All	N/A; Reference Only	5.1	General Reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A

AP-3.15Q.1

Rev. 06/30/1999

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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1. Document Identifier No./Rev.: ANL-NBS-MD-000009 REV 00		Change:	Title: Evaluate Soil/Radionuclide Removal by Erosion and Leaching						
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2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
36	Woodruff, N.P. and Siddoway, F.H. 1965. "A Wind Erosion Equation." <i>Soil Science Society of America Proceedings</i> , 29 (5), 602-608. Madison, Wisconsin: Soil Science Society of America. TIC: 246058.	All	N/A; Reference Only	5.1	General Reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
37	Yoder, D. and Lown, J. 1995. "The Future of RUSLE: Inside the New Revised Universal Soil Loss Equation." <i>Journal of Soil and Water Conservation</i> , 50 (5), 484-489. Ankeny, Iowa: Soil Conservation Society of America. TIC: 246069.	All	N/A; Reference Only	5.1	General Reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
38	<i>Soil Conservation and Domestic Allotment Act of 1935.</i> (Public Law 74-46, 49 Stat. 163).	Chapter 85	N/A; Reference Only	5.1	General Reference to provide background and scientific information to report.	N/A	N/A	N/A	N/A
38	64 FR 8640. Disposal of High Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain. TIC: 242725. Readily Available.	All	N/A, Reference Only	1.0	Regulatory document describing critical group characteristics	N/A	N/A	N/A	N/A
40	AP-SI.1Q, Rev. 2, ICN 1. <i>Software Management</i> . Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19991101.0212.	Section 5.1	N/A, Reference Only	3.0	General reference to a project quality assurance procedure.	N/A	N/A	N/A	N/A
41	AP-SIII.3Q, Rev. 0, ICN 1. <i>Submittal and Incorporation of Data to the Technical Data Management System</i> . Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19990831.0078.	All	N/A, Reference Only	2.0	General reference to a project quality assurance procedure.	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
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1. Document Identifier No./Rev.: ANL-NBS-MD-000009 REV 00		Change:	Title: Evaluate Soil/Radionuclide Removal by Erosion and Leaching						
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2. Technical Product Input Source Title and Identifier(s) with Version							Unqual.	From Uncontrolled Source	Un-confirmed
42	AP-3.10Q, Rev. 1, ICN 0. <i>Analyses and Models</i> . Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19990702.0314.	All	N/A, Reference Only	2.0	General reference to a project quality assurance procedure.	N/A	N/A	N/A	N/A
43	NLP-2-0, Rev. 5. <i>Determination of Importance Evaluations</i> . Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981116.0120.	All	N/A, Reference Only	2.0	General reference to a project quality assurance procedure.	N/A	N/A	N/A	N/A
44	QAP-2-0, Rev. 5. <i>Conduct of Activities</i> . Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980826.0209.	All	N/A; Reference Only	2.0	Provided guidance for producing quality affecting work	N/A	N/A	N/A	N/A
45	QAP-2-3, Rev. 10. <i>Classification of Permanent Items</i> . Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990316.0006.	All	N/A, Reference Only	2.0	Quality assurance guidance	N/A	N/A	N/A	N/A

**ATTACHMENT II – SOFTWARE ROUTINE VERIFICATION DOCUMENTATION
AND CODE LISTING**



Sandia National Laboratories

Operated for the U.S. Department of Energy by
Sandia Corporation

Albuquerque, New Mexico 87185-0778

WBS: 1.2.3

att

QA: QA

8/26/99

date: August 12, 1999

to: Mario Chavez, 6850/JHA
SNL YMP Software Configuration Management Coordinator

from: Ron McCurley, 6851/NMERI

subject: SOIL MODEL Version A1.20 Software Routine Verification (Documentation of eng.
Soil Model Program to Calculate Leaching Factors) 8/26/99
Calculation of Leaching Factors (Richard Aguilar & Ron McCurley, SNL-PAO)
AMR - 80050 "Evaluate Soil/Radionuclide Removal by Erosion & Leaching - ANL-NBS-MD-000009.
A software routine (consisting of several modules) was developed in accordance with AP-SI.1Q for the
purpose of calculating leaching factors to be used by GENII-S in the development of BDCF's. The
software developed, SOIL MODEL, version A1.20, is in FORTRAN 77. The source code and
executable reside in the following directory location on a DEC ALPHA at Sandia National Laboratories:

II:[000000.RDMCCUR.INEEL_PA98.YMP_99.BIOSPHERE.SOIL_MODEL.SOURCE_COD
E].

The equation used to determine the calculated leaching factors ($\lambda_{s,k}$) adapted from Baes and Sharp (1983) is:

$$\lambda_{s,k} = (P + I - E) / [D_s * \theta_s * (1.0 + \rho_s / \theta_s * K_{d,s,k})] \text{ where}$$

P, I, and E are the annual precipitation, irrigation, and evapotranspiration rates [cm/yr]

D_s = Depth of surface soil [m]

θ_s = Volumetric water content of soil [ml/cc]

ρ_s = Surface soil bulk density [g/cc]

$K_{d,s,k}$ = Surface soil solid/liquid partition coefficient, K_d , for nuclide "k" (isotope independent) and soil type "s"

For this calculation, the parameters on the right side of the equation have been assigned (see attached table for K_d values) the following values:

Soil bulk density (ρ_s) = 1.5 g/cm³

Soil (topsoil) depth (D_s) = 15.0 cm

Volumetric soil water content (θ_s) = 0.217 ml/cm³

Natural precipitation (P) = 3.51 in/yr (8.91 cm/yr)

Irrigation rate (I) = 86.99 in/yr (220.95 cm/yr)

Evapotranspiration (E) = 84.50 in/yr (214.63 cm/yr)

$$(i.e., P + I - E = 15.23 \text{ cm/yr})$$

Documentation of input

P, I, and E values were obtained from ANL-MGR-MD-000001, Rev. 00A - *Input Parameter Values for External and Inhalation Radiation Exposure Analysis*. P.E. Lederle - Originator; Draft, August 1999.

The K_{ds} values are from one source: Sheppard & Thibault (1990), for sandy soils Baes and Sharp (1983) and LaPlante & Poor (1997) also recommend the use of the K_{ds} reported in Sheppard.

Volumetric water content we used (0.217 ml/cm^3) was that value that corresponds to field capacity (1/3 bar) for sandy loam soils (Baes and Sharp, 1983).

Bulk densities (ρ_s) in the range of 1.50 g/cm^3 are typical for the sandy soils that exist in Armagosa Valley.

The depth of surface soil (D_s) is reasonable for agricultural soils.

Results:

Below are selected radionuclides with corresponding input K_{ds} in the second column, the calculated (by SOIL_MODEL) leaching coefficients and the values as calculated using a HP 32S (Hewlett Packard) calculator with input values as specified above substituted in the leaching equation, also as specified above.

Radionuclide	K_d	Leaching coefficient	
		SOIL_MODEL (3 significant digits)	calculator (4 significant digits)
TC99	1.00E-01	2.77E+00	2.767E+00
I129	1.00E+00	5.92E-01	5.913E-01
PU242	5.50E+02	1.23E-03	1.230E-03

The table above shows a verification of the calculation of leaching coefficients over a range of K_{ds} by the code SOIL_MODEL.

Literature Cited:

- Baes C. F., III and R. D. Sharp. 1983. A proposal for estimation of soil leaching constants for use in assessment models. *J. Environ. Qual.* 12:17-28.
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YMP:1.2.1.12:SFT:Q:SOIL_Model Version A1.20, Software Routine Verification

8/26/99 emj HandCopy Listing of Source Code for Soil Model Routine 8/12/99

PROGRAM SOILMODEL

MOL.19991011.0125

SOILMODEL

The SOILMODEL program calculates changes in radionuclide distributions in the surface soil due to leaching, erosion

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Abstract

Translates input parameters used in (1) the leaching equation from Baes & Sharp to a leaching rate, (2) the USLE (Universal Soil Loss Equation) to an surface soil removal rate due to water erosion.

Primary Reference

Baes & Sharp 1983

Update History

Version	Date	Modified by	Changes
DEC ALPHA A1.00	June, 1999	Ron D. McCurley	Original version
DEC ALPHA A1.20	July 2, 1999	Ron D. McCurley	Added additional radionuclides
DEC ALPHA A1.22	Aug 6, 1999	Ron D. McCurley	Added additional radionuclide Mo93, fix for English units (inches)

Disclaimer

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```

70 C
71 C
72 C
73 C
74 C EXDATE: Returns the current date in a character string.
75 C EXTIME: Returns the current time in a character string.
76 C EXCPUS: Returns accumulated CPU time, in seconds.
77 C EXPARM: Returns the operating environment parameters.
78 C FFRDLRDS: Substitute for subroutine FREFLD, input is prompted for, read,
79 C and echoed, using specified I/O units.
80 C SOILMODEL: SOILMODEL program main driver.
81 C PREPRO: SOILMODEL input preprocessor which performs QA functions and calls
82 C routine for parsing command line arguments consisting of
83 C filenames. Those files are opened when appropriate or prompted
84 C for if not supplied on the command line or set to defaults.
85 C PROCTL: Processes SOILMODEL input control file, and determines new
86 C parameters needed for INFIL control file.
87 C QAABORT: Prints a fatal error message and then aborts job in case of error
88 C detected in input.
89 C QABANNER: Prints the program banner to the terminal or an output file.
90 C The banner includes the program name in large letters, the program
91 C description, the version, the revision date, the author, the
92 C sponsor, and the current run date and time.
93 C QADOEDIS: Prints the Sandia DOE contract statement and the DOE disclaimer
94 C to the terminal or an output file.
95 C QAFETCH: Returns the program QA information. Routine QASETUP must be
96 C called to set up the CAMCON_LIB common before QAFETCH is called.
97 C QAPAGE: Starts a new page (except for the first call) and puts the QA
98 C information (program name, run time, etc.) at the top of each
99 C page. At the end of the file, it prints the ending QA
100 C information.
101 C QAMAXERR: Checks an integer value against a maximum value. If the value is
102 C over the maximum, an error message is printed and QAABORT is
103 C called (if requested).
104 C QASETUP: Called at the start of the program. It performs initialization
105 C details common to all programs. Specifically, it:
106 C     Initializes the CPU time,
107 C     Sets the common area CAMCON_LIB common with the passed
108 C     information,
109 C     Sets the current run date and time,
110 C     Sets the execution machine and operating system,
111 C     Adds the machine to the program version,
112 C     Starts a new page on the terminal.
113 C RDPAR: Reads the SOILMODEL input control file parameter information
114 C and returns the variables found.
115 C TYPRQS: Outputs a request for a character string and then inputs the
116 C character string in an interactive session.
117 C WELCOM: Produces instructions for main program usage, writes banner and
118 C program credits.

```

Subroutine Flowchart

```

120 C
121 C
122 C
123 C SOILMODEL--QASETUP--EXCPUS
124 C
125 C     +-EXPARM
126 C
127 C     +-STRPACK
128 C
129 C     +-EXDATE
130 C
131 C     +-EXTIME
132 C
133 C +-QAFETCH
134 C
135 C +-PREPRO--EXPARM
136 C
137 C +-RDCMDL
138 C
139 C +-WELCOM--QABANNER

```

soil.for;3

```
140 C
141 C      +-TYPRQS
142 C
143 C      +-QABANNER
144 C
145 C      +-QAPAGE
146 C
147 C      +-QADOEDIS
148 C
149 C      +-PROCTL+-RDPAR+-FFRDLRDS
150 C
151 C      +-QAABORT
152 C
153 C      +-LEACH+-GETKD
154 C
155 C      +-EXCPUS
156 C
157 C      +-QAPAGE
158 C
159 C
```

Assumptions and Limitations

```
160 C
161 C
162 C
163 C      Language used is ANSI X3.9-1978 FORTRAN 77 except that comments
164 C      and Hollerith strings use lowercase characters. INTEGER and REAL
165 C      variable names are explicitly typed. Machine dependent coding
166 C      exists in subroutine WRI
167 C
```

Statistics

```
168 C
169 C
170 C
171 C      ALPHA Version 2.02:
172 C      12659 lines total, 6730 FORTRAN lines, 5508 FORTRAN statements
173 C      5930 comment lines, 3487 text lines,
174 C      total/FORTRAN lines ratio: 1.881
175 C
```

Types of data sets

```
176 C
177 C
178 C
179 C      INPUT/
180 C      ASCII: in units INASCI, KDLIB
181 C
182 C      OUTPUT/
183 C      ASCII: in units IOUT, NOUTFL
184 C
```

Files used

```
185 C
186 C
187 C
188 C      filename      unit      description
189 C      SYSS$COMMAND      5      Terminal screen/keyboard
190 C      (SOILMODEL_SXX.DBG) 6 or 7 (OPTIONAL) SOILMODEL diagnostics/debug file
191 C      (SOILMODEL_SXX.INP) 8      SOILMODEL input control file
192 C      (SOILMODEL_SXX.OUT) 9      SOILMODEL output file generated by SOILMODEL
193 C
```

```
194 C*****
195 C234567
```

```
196 C      IMPLICIT NONE
197 C      INCLUDE 'IOCOM.INC/LIST'
198 C      INCLUDE 'PARAMS.INC/LIST'
199 C      INCLUDE 'CAMCON_COMMON.INC/LIST'
200 C
201 C      INTEGER IERR, MORMEMC, MORMEMR, NUMNUC
202 C      REAL RDUM
203 C      REAL ALAMLCH(MAXNUC)
204 C
205 C      CHARACTER*12 INPROG
206 C      CHARACTER*8 INVERS, INDATE
207 C      CHARACTER*8 NAMNUC(MAXNUC)
208 C      CHARACTER*80 INAUTH, INSPON
209 C      CHARACTER*80 FOUT, FDBG, FLIB, FUSR
```

```

110 LOGICAL WRTOUT
111
112 EXTERNAL BLOCK
113
114
115 C<><><><><><><><><><>
116 C...Begin Procedures...
117 C<><><><><><><><><><>
118
119 C      ...Perform routine initializations
120 CALL QASETUP ( PROGRAM, PVERSN, PDATE, AUTHOR, SPONSR )
121 C
122 C      ...Call for program QA information
123 CALL QAFETCH (PROGRAM, PVERSN, PDATE, RUNDAT, RUNTIM,
124 &             AUTHOR, SPONSR)
125 C
126 C      ...Prompt USER for program execution control options
127 CALL PREPRO( FUSR, FLIB, FOUT, FDBG )
128
129 C
130 C**** Process the SOILMODEL input control file ****
131 C
132 C      ...Read SOILMODEL input control file first time
133 OPEN(INASCI,FILE=FUSR,STATUS='UNKNOWN',
134 +     FORM='FORMATTED',READONLY)
135 CALL PROCTL
136
137 CLOSE(INASCI)
138 OPEN(KDLIB,FILE=FLIB,STATUS='UNKNOWN',
139 +     FORM='FORMATTED',READONLY)
140 CALL LEACH(ALAMLCH)
141 CLOSE(KDLIB)
142 C      ...Show USER the program status
143 PRINT *, ' *** Completed processing input data to produce output ',
144 +        'leaching factors ***'
145 C
146 IERR = 0
147 C      ...Set debugging/diagnostics file unit
148 CALL DBERRUNI( NOUTFL )
149 C
150 C**** Begin program termination procedures ****
151 C
152 CALL EXCPUS( RDUM )
153 WRITE(NOUTFL,('(A,F10.4,A)') ' CPU time was',RDUM,' seconds'
154 CALL QAPAGE(NOUTFL,'END')
155 CLOSE(NOUTFL)
156 STOP 'SOILMODEL Normal Completion'
157 C-----
158 C**** END OF PROGRAM SOILMODEL (A1MAIN) ****
159 C-----
160 END
161
162
163 *COMDECK BLOCK
164 BLOCK DATA BLOCK
165 C*****
166 INCLUDE 'TOCOM.INC/LIST'
167 INCLUDE 'CAMCON_COMMON.INC/LIST'
168 INCLUDE 'PARAMS.INC/LIST'
169 C*   INCLUDE 'INDEX.INC/LIST'
170 C*   INCLUDE 'DYNAME.INC/LIST'
171 INCLUDE 'NUCDAT.INC/LIST'
172 INCLUDE 'SOIL.INC/LIST'
173 INCLUDE 'WATER.INC/LIST'
174
175 CHARACTER*80 LINE1,LINE2,LINE3
176 COMMON /L1/ LINE1
177 COMMON /L2/ LINE2
178 COMMON /L3/ LINE3
179

```

soil.for;3

```
280 C      ...Dynamic array names (COMMON /DYNAME/)
281 C*     DATA DTYPES/
282 C*     $'INTEGER','INTEGER','LOGICAL','REAL'/
283 C*     DATA RNames/
284 C*     $'IDBLK','NUMPRP','IASPRP','XMATPR'/
285 C*     DATA CNames/
286 C*     $'QAINFO','NAMELB','NMATPR'/
287
288 DATA ITEMP1/1/ICDB/4/ISCREN/5/
289 + INASCI/2/KDLIB/11/,IOUTFL/8/
290
291 C      LASRIDX= Last index of REAL dynamic arrays [INTEGER]
292 C*     DATA LASCIDX/3/LASRIDX/4/
293
294 DATA
295 +LINE1/'The SOILMODEL program uses available data from research '/
296 +LINE2/'papers to calculate leaching and erosion factors based on'/
297 +LINE3/' characteristic soils for Armagosa Valley'/
298
299 DATA PROGRAM / 'SOILMODEL' /
300 DATA PVERSN / 'A1.22' /
301 DATA PDATE / '08/06/99' /
302 DATA AUTHOR / 'Ron McCurley' /
303 DATA SPONSR / 'Ron McCurley' /
304 DATA NUMNUC/8/
305 DATA NAMNUC/'C14','Cl36','Ni59','Ni63','Se79','Sr90','Zr93',
306 + 'Mo93','Nb93m','Nb94','Pd107','Sb126','Sn126','I129',
307 + 'Cs137','Sm151','Bi210','Pb210',
308 + 'Po210','Pu239','Ra225','Tc99','Th229','Pa231',
309 + 'U233','U234','U235','U236','U238',
310 + 'Cm244','10*' /
311 DATA DEPTHS/0.15/RHOGRN/2.64E+03/RHOS/1.4E+03/THETA1/0.24/
312 + THETA2/0.29/THETA3/0.15/THETA4/0.23/
313 DATA ET/10.0/IRRIG/20.0/PRECIP/15.0/
314 DATA FRSATP/0.0054/,FRPRET/0.68/,FRSATI/0.2/,FRIRET/0.5/
315 DATA MODEL/'BAES_SHARP'/
316 *****
317 END
318
319
320 *DECK GETKD
321 SUBROUTINE GETKD(NUMNUC,NAMENUC,SOILTYPE,ELT,KD)
322 C*****
323 C
324 INCLUDE 'IOCOM.INC/LIST'
325 INCLUDE 'PARAMS.INC/LIST'
326 INCLUDE 'SOIL.INC/LIST'
327 INTEGER IELT, INUC, K, NELT, NUMNUC
328 REAL KDSOIL(MAXNUC,MAXTYP), KD(*)
329 CHARACTER*2 ELT(*)
330 CHARACTER*8 NAMENUC(*),SOILTYPE
331 CHARACTER*80 HEAD1, HEAD2
332 LOGICAL FINDIT(MAXNUC)
333
334 NTYP = 5
335 IELT = 0
336 C      ...read 1st 2 lines of comments
337 READ (KDLIB,1000,END=99) HEAD1
338 READ (KDLIB,1000,END=99) HEAD2
339 1000 FORMAT(A80)
340 20 CONTINUE
341 IELT = IELT + 1
342
343 READ (KDLIB,1001,END=99) ELT(IELT), (KDSOIL(IELT,K),K=1,NTYP)
344 1001 FORMAT(1X,A2,7X,5(E9.2,1X))
345 GO TO 20
346 99 NELT = IELT - 1
347 DO 200 INUC=1,NUMNUC
348 FINDIT(INUC) = .FALSE.
349 DO 100 IELT=1,NELT
```

soil.for;3

```
350
351 IF (NAMENUC(INUC)(1:2).EQ.ELT(IELT) ) THEN
352   FINDIT(INUC) = .TRUE.
353   IF (SOILTYPE(1:4).EQ.'SAND') THEN
354     KD(INUC)=KDSOIL(IELT,1)
355   ELSEIF (SOILTYPE(1:4).EQ.'LOAM') THEN
356     KD(INUC)=KDSOIL(IELT,2)
357   ELSEIF (SOILTYPE(1:4).EQ.'CLAY') THEN
358     KD(INUC)=KDSOIL(IELT,3)
359   ELSEIF (SOILTYPE(1:4).EQ.'ORGA') THEN
360     KD(INUC)=KDSOIL(IELT,4)
361   ELSEIF (SOILTYPE(1:4).EQ.'BAES') THEN
362     KD(INUC)=KDSOIL(IELT,5)
363   ENDIF
364   ELSEIF( (NAMENUC(INUC)(1:2).EQ.'U2' .OR.
365     +      NAMENUC(INUC)(1:2).EQ.'I1' .OR.
366     +      NAMENUC(INUC)(1:2).EQ.'C1') .AND.
367     +      NAMENUC(INUC)(1:1).EQ.ELT(IELT)(1:1) ) THEN
368     FINDIT(INUC) = .TRUE.
369     IF (SOILTYPE(1:4).EQ.'SAND') THEN
370       KD(INUC)=KDSOIL(IELT,1)
371     ELSEIF (SOILTYPE(1:4).EQ.'LOAM') THEN
372       KD(INUC)=KDSOIL(IELT,2)
373     ELSEIF (SOILTYPE(1:4).EQ.'CLAY') THEN
374       KD(INUC)=KDSOIL(IELT,3)
375     ELSEIF (SOILTYPE(1:4).EQ.'ORGA') THEN
376       KD(INUC)=KDSOIL(IELT,4)
377     ELSEIF (SOILTYPE(1:4).EQ.'BAES') THEN
378       KD(INUC)=KDSOIL(IELT,5)
379     ENDIF
380   ENDIF
381
382 100 CONTINUE
383 IF (FINDIT(INUC) .EQ. .FALSE.) THEN
384   WRITE(NOUTFL,1002) NAMENUC(INUC)(1:2)
385 1002 FORMAT(1X,'Could not find element ',A2,' in Kd library')
386 ENDIF
387 200 CONTINUE
388
389 RETURN
390 END
391
392
393 *DECK LEACH
394 SUBROUTINE LEACH(ALAMLCH)
395 C*****
396 C
397 C
398 INCLUDE 'IOCOM.INC/LIST'
399 INCLUDE 'PARAMS.INC/LIST'
400 INCLUDE 'NUCDAT.INC/LIST'
401 INCLUDE 'SOIL.INC/LIST'
402 INCLUDE 'WATER.INC/LIST'
403 INTEGER I,K
404 REAL OVERWAT,THETA,SOILFAC,SOILH2O,UNTPRD,XNUMER
405 REAL ALAMLCH(MAXNUC), KD(MAXNUC), UNTCNV(3)
406 CHARACTER*(2) ELT(MAXNUC)
407
408 C* UNTCNV/1.0E-2,1.0E3,1.0E-6/
409 IF (UNITS_SOIL.EQ.'CGS' .AND. UNITS_H2O.EQ.'CGS') THEN
410 C   ...This is default!
411   DO 10 I=1,3
412     UNTCNV(I) = 1.0
413 10 CONTINUE
414 ELSEIF (UNITS_H2O.EQ.'ENG') THEN
415 C   ...using inches for water amounts
416   UNTCNV(1) = 2.54
417   DO 15 I=2,3
418     UNTCNV(I) = 1.0
419 15 CONTINUE
```

soil.for;3

```
120      ENDIF
121      IF (SOILCAT(1:4).EQ.'SILT') THETA = THETA1
122      IF (SOILCAT(1:4).EQ.'CLAY') THETA = THETA2
123      IF (SOILCAT(1:4).EQ.'SAND') THETA = THETA3
124      IF (SOILCAT(1:4).EQ.'ORGA') THETA = THETA4
125      IF (SOILCAT(1:4).EQ.'BAES') THETA = THETA4
126
127      UNTPRD=UNTCNV(2)*UNTCNV(3)
128 C      ..."overwatering term"
129      OVERWAT = (PRECIP + IRRIG - ET)
130
131 C      ...alternative formulation from Jarzemba & Manteufel (modified from
132 C      Napier et al)
133      IF (MODEL(1:5).EQ.'ALTER') THEN
134          XNUMER = PRECIP*FRSATP*(1.0 - FRPRET) +
135          +      IRRIG*FRSATI*(1.0 - FRIRET)
136      ELSE
137          XNUMER = OVERWAT*UNTCNV(1)
138      ENDIF
139      SOILH2O = THETA*DEPTHS
140      SOILFAC = UNTPRD*RHOS/THETA
141      WRITE(NOUTFL,1000)
142 1000 FORMAT('      Precip Irrig      ET      Water content Porosity ',
143  +      'Bulk den      Depth')
144      WRITE(NOUTFL,1001) PRECIP,IRRIG,ET,THETA,POROSITY,RHOS,DEPTHS
145 1001 FORMAT(7F10.2)
146 C      ...get kds for this soil type
147      CALL GETKD(NUMNUC,NAMNUC,SOILCAT(1:4),ELT,KD)
148      WRITE(NOUTFL,1002)
149 1002 FORMAT('Element/nuclide kd      leaching factor//')
150 C**** calculate leaching factors
151      DO 200 K=1,NUMNUC
152          ALAMLCH(K) = XNUMER/(SOILH2O*(1.0 + SOILFAC*KD(K)))
153          PRINT *, NAMNUC(K), KD(K), ALAMLCH(K)
154          WRITE(NOUTFL,1003) NAMNUC(K), KD(K), ALAMLCH(K)
155 1003 FORMAT(2X,A8,2(1PE9.2,2X))
156 200 CONTINUE
157      RETURN
158      END
159
160
161 *DECK,PREPRO
162      SUBROUTINE PREPRO( FUSR, FLIB, FOUT, FDBG )
163 C*****
164 C
165 C      PURPOSE:      PREPRO input preprocessor which performs:
166 C                    1. QA functions
167 C                    2. Calls routine for parsing command line argUements
168 C                    which consists of filenames. Those files are
169 C                    opened when appropriate or prompted for if not
170 C                    supplied on the command line or set to defaults.
171 C
172 C      AUTHOR:      Ron D McCurley
173 C
174 C      UPDATED:      07 May, 1999  --
175 C
176 C      CALLED BY:    SOILMODELIL (main program)
177 C
178 C      CALLS:      EXPARM
179 C                  FILCMDLIN
180 C                  WELCOM
181 C                  TYPROS
182 C                  ISTRLEN
183 C                  QABANNER
184 C                  QAPAGE
185 C                  QADOEDIS
186 C
187 C      ARGUMENTS:
188 C      ENTRY/
189 C      --common blocks
```



```

490 C /IOCOM/ ($include 'IOCOM.INC')
491 C NOUTFL = Device no. of diagnostics/debug output file
492 C (Equilibrated to NOUTFL)
493 C /L1/ Contains Line 1 of a 3-line program discription written out
494 C following the program banner
495 C /L2/ Contains Line 2 of a 3-line program discription written out
496 C following the program banner
497 C /L3/ Contains Line 3 of a 3-line program discription written out
498 C following the program banner
499 C
500 C LOCAL/
501 C NFILES = Maximum nUmer of files on command line
502 C BATCHF = Logical BATCH process flag
503 C INTRAF = Logical INTERACTIVE process flag
504 C ERRORF = Logical ERROR flag
505 C HARD = System hardware ID
506 C SOFT = System software ID
507 C MODE = BATCH(0) or INTERACTIVE(1) mode
508 C KCSU = Characters Units per base Unit
509 C KNSU = Numeric storage Units per base Unit
510 C IDAU = Units of storage which define size of Unformatted
511 C direct I/O records 0=character, 1=nUmeric
512 C
513 C EXIT/
514 C --common block
515 C /IOCOM/ ($include 'IOCOM.INC')
516 C NOUTFL = Device no. of diagnostics/debug output file
517 C
518 C --through subroutine call
519 C FUSR = SOILMODEL Control Card Data filename
520 C FCDB = Calculational data base filename
521 C FLIB = SOILMODEL Kd library file
522 C FOUT = SOILMODEL program output file
523 C FDBG = SOILMODEL program diagnostics/debug filename
524 C
525 C -----
526 C234567
527 IMPLICIT NONE
528 INTEGER ISTRLEN
529 INCLUDE 'IOCOM.INC/LIST'
530 COMMON /L1/ LINE1
531 COMMON /L2/ LINE2
532 COMMON /L3/ LINE3
533
534 INTEGER I, IDAU, KCSU, KNSU, MODE, NFILES
535 LOGICAL EXIST, BATCHF, ERRORF, INTRAF
536 CHARACTER*8 HARD, SOFT
537 CHARACTER*(*) FUSR, FLIB, FOUT, FDBG
538 CHARACTER*80 FILESP(4)
539 CHARACTER*80 LINE1,LINE2,LINE3
540
541 C<><><><><><><><><><><><><><>
542 C...BEGIN PROCEDURES...
543 C<><><><><><><><><><><><><><>
544
545 C ...Check if current run is BATCH or INTERACTIVE
546 C BATCH -> messages to debug file
547 C INTER -> messages to screen
548 CALL EXPARM(HARD,SOFT,MODE,KCSU,KNSU,IDAU)
549 IF (MODE.EQ. 0) THEN
550 BATCHF = .TRUE.
551 ELSE
552 BATCHF = .FALSE.
553 ENDIF
554
555 C ...Get files names from command line
556 C FILESP(1 to 4) are: FUSR, FLIB, FOUT, FDBG
557 C ...If FUSR = 'default' all files will be defaulted, otherwise
558 C they will be prompted for. A blank response to the prompt will
559 C also result in default file name.
```

```

560 ERRORF = .FALSE
561 CALL FILCMDLIN(4,NFILES,FILESP)
562 FUSR = FILESP(1)
563 FLIB = FILESP(2)
564 FOUT = FILESP(3)
565 FDBG = FILESP(4)
566
567 C    ...If any files specified on command line set INTRAF to false
568 INTRAF = .TRUE.
569 IF (NFILES .GT. 0) THEN
570     INTRAF = .FALSE.
571     BATCHF = .TRUE.
572 ELSE
573     INTRAF = .TRUE.
574 ENDIF
575
576 IF (INTRAF) THEN
577 C    ...INTERACTIVE: Prompt for filenames
578
579     CALL WELCOM
580     WRITE(*,1000)
581 C
582 C    -----
583 C    SOILMODEL Control Card Data file
584 C    -----
585
586 100 CALL TYPRQS(' Enter SOILMODEL Control Card Data filename'//
587 +             '<SOILMODEL.INP>',FUSR)
588 C    ...Null response implies default
589 IF (FUSR .EQ. 'default' .OR. FUSR .EQ. 'DEFAULT' .OR.
590 &    FUSR .EQ. ' ') FUSR = 'SOILMODEL.INP'
591 INQUIRE(FILE=FUSR, EXIST=EXIST)
592 IF (.NOT. EXIST) THEN
593     WRITE(*,'(3A/)' )
594 &    ' FUSR=' ,FUSR(1:ISTRLEN(FUSR)), ' does not exist'
595     FUSR = ' '
596     GOTO 100
597 ENDIF
598
599 C    -----
600 C    COMPUTATIONAL data base
601 C    -----
602 C
603 C    ...Prompt User for COMPUTATIONAL data base
604 C 200 CALL TYPRQS(' Enter COMPUTATIONAL data base filename'//
605 +             '<POSTLHS.CDB>',FCDB)
606 C    ...Null response implies default
607 C* IF (FCDB .EQ. 'default' .OR. FCDB .EQ. 'DEFAULT' .OR.
608 C* &    FCDB .EQ. ' ') FCDB='POSTLHS.CDB'
609 C* INQUIRE(FILE=FCDB, EXIST=EXIST)
610 C* IF (.NOT. EXIST) THEN
611 C*     WRITE(*,'(3A/)' )
612 C* &    ' FCDB=' ,FCDB(1:ISTRLEN(FCDB)), ' does not exist'
613 C*     FCDB = ' '
614 C*     GOTO 200
615 C* ENDIF
616
617 C    -----
618 C    SOILMODELIL output file
619 C    -----
620 C
621 C    ...Prompt User for SOILMODEL output filename
622 CALL TYPRQS(' Enter SOILMODEL output filename'//
623 +             '<LEACH.OUT>',FOUT)
624 C    ...Null response implies default
625 IF (FOUT .EQ. 'default' .OR. FOUT .EQ. 'DEFAULT' .OR.
626 &    FOUT .EQ. ' ') FOUT = 'LEACH.OUT'
627
628 C    -----
629 C    Diagnostics/Debug output file

```

soil.for;3

```
630 C -----
631 C
632 WRITE(*,1100)
633 C ...Prompt User for OPTIONAL diagnostics/debug file
634 CALL TYPRQS(' Enter (optional) SOILMODEL diagnostics/debug'//
635 + ' filename <SOILMODEL.DBG>',FDBG)
636 C ...Null response implies default
637 IF (FDBG .EQ. 'default' .OR. FDBG .EQ. 'DEFAULT' .OR.
638 & FDBG .EQ. ' ') FDBG='SOILMODEL.DBG'
639 IF (FDBG(:3) .EQ. 'CAN' .OR. FDBG(:3) .EQ. 'can') THEN
640 C ...Don't write a recoverable diagnostics/debug file
641 NOUTFL = 6
642 FDBG = 'SOILMODEL.SCR'
643 ELSE
644 NOUTFL = 7
645 ENDIF
646
647 ELSE
648
649 C ...Set Undefined files to defaults and check for existence
650 IF (FUSR .EQ. 'default' .OR. FUSR .EQ. 'DEFAULT' .OR.
651 & (BATCHF .AND. FUSR .EQ. ' ') ) FUSR = 'SOILMOD.INP'
652 INQUIRE(FILE=FUSR,EXIST=EXIST)
653 IF (.NOT.EXIST) THEN
654 WRITE(*,'(3A/)')
655 & ' FUSR=',FUSR(1:ISTRLEN(FUSR)), ' does not exist'
656 ERRORF = .TRUE.
657 ENDIF
658
659 C* IF (FCDB .EQ. 'DEFAULT' .OR. FCDB .EQ. 'default' .OR.
660 C* & (BATCHF .AND. FCDB .EQ. ' ') ) FCDB = 'POSTLHS.CDB'
661 C* INQUIRE(FILE=FCDB,EXIST=EXIST)
662 C* IF (.NOT.EXIST) THEN
663 C* WRITE(*,'(3A/)')
664 C* & ' FCDB=',FCDB(1:ISTRLEN(FCDB)), ' does not exist'
665 C* ERRORF = .TRUE.
666 C* ENDIF
667
668 IF (FOUT .EQ. 'default' .OR. FOUT .EQ. 'DEFAULT' .OR.
669 & (BATCHF .AND. FOUT .EQ. ' ') ) FOUT = 'LEACH.OUT'
670
671 IF (FDBG .EQ. 'default' .OR. FDBG .EQ. 'DEFAULT' .OR.
672 & (BATCHF .AND. FDBG .EQ. ' ') ) FDBG = 'SOILMODELIL.DBG'
673
674 IF (FDBG(:3).EQ. 'CAN' .OR. FDBG(:3).EQ. 'can') THEN
675 C ...Don't write a recoverable diagnostics/debug file
676 NOUTFL = 6
677 FDBG = 'SOILMODELIL.SCR'
678 ELSE
679 NOUTFL = 7
680 ENDIF
681 ENDIF
682
683 C ...Open Diagnostics/Debug output file
684 IF (NOUTFL.EQ.7) THEN
685 OPEN(NOUTFL,FILE=FDBG,FORM='FORMATTED',STATUS='UNKNOWN')
686 ELSEIF (NOUTFL.EQ.6) THEN
687 OPEN(NOUTFL,FILE=FDBG,STATUS='SCRATCH')
688 ENDIF
689
690 C ...Write QA stuff
691 CALL QABANNER(NOUTFL,LINE1,LINE2,LINE3)
692 CALL QAPAGE(NOUTFL,' ')
693 CALL QADOEDIS(NOUTFL,'*')
694
695 WRITE(NOUTFL,1200)
696 WRITE(NOUTFL,'(A)') ' FILE ASSIGNMENTS'
697 WRITE(NOUTFL,'(A)') ' -----'
698 WRITE(NOUTFL,'(A,A)') ' SOILMODELIL Input Control FILE.....',
699 + FUSR(1:40)
```

soil.for;3

```
700 C*      WRITE(NOUTFL,'(A,A)') ' COMPUTATIONAL Data Base FILE.....',
701 C*      +      FCDB(1:40)
702      WRITE(NOUTFL,'(A,A)') ' SOILMODEL output FILE.....',
703      +      FOUT(1:40)
704      WRITE(NOUTFL,'(A,A)') ' DIAGNOSTICS/DEBUG Output FILE.....',
705      +      FDBG(1:40)
706
707 C      ...Stop if ERRORF
708      IF (ERRORF) THEN
709          WRITE(NOUTFL,'(A)') ' FILE SPECIFICATION ERROR(S)'
710          STOP '*** FILE SPECIFICATION ERROR(S) IN PREPRO ***'
711      ENDIF
712      RETURN
713 C
714 C----- F O R M A T   S T A T E M E N T S -----
715 C
716 1000 FORMAT(/,' ...For <default filenames>, press RETURN',/)
717 1100 FORMAT(/,' ...To CANCEL optional files requested, respond',
718      +      ' with: CANCEL',/)
719 1200 FORMAT(/,79(' '),/1X,' (PREPRO)')
720 C
721 C-----
722 C**** END OF subroutine PREPRO ****
723 C-----
724      END
725
726
727 *DECK, PROCTL
728      SUBROUTINE PROCTL
729 C*****
730 C***
731 C***      P_R_Ocess  input  C_on_T_ro_L File  module      ****
732 C***      - - - - -      - - - - -      ****
733 C*****
734 C
735 C  PURPOSE :      Reads the SOILMODEL input control file and RETURNS the
736 C                  variables which will be modified from the template file
737 C                  (i.e.--the sampled parameters).  May also return file
738 C                  names as used by INFIL
739 C
740 C  AUTHOR:      Ron D McCurley
741 C
742 C  UPDATED:      May, 1999
743 C
744 C  CALLED BY:      SOILMODEL
745 C
746 C  CALLS:      FFRDFLDS
747 C                  DOECHO
748 C                  RETRIE
749 C                  QAABORT
750 C
751 C  ARGUMENTS:
752 C  ENTRY/
753 C      --common blocks
754 C      /IOCOM/ ($include 'IOCOM.INC')
755 C      INASCI = File unit of PRELHS input control file
756 C      NOUTFL = "      diagnostics/debug file
757 C
758 C      /FFRDAT/ ($include 'FFRDAT.INC')
759 C      MFIELD = Max. no. of fields that Free-Field-Reader can process
760 C      NFORM = Max. length of a CHARACTER data field
761 C
762 C  LOCAL/
763 C      CVALUE = CHARACTER values of the data fields
764 C      IERR = INTEGER error flag
765 C      IOSTAT = INTEGER value for ANSI FORTRAN I/O status
766 C      IVALUE = INTEGER values of the data fields
767 C      KVALUE = Translation states of the data fields
768 C      NFIELD = Number of fields
769 C      RVALUE = REAL values of the data fields
```

```
soil.for;3
```

```

770 C EXIT/
771 C --through subroutine call
772 C NUMVAR = No. of LHS variables
773 C
774 C *****
775 C234567
776 IMPLICIT NONE
777 INCLUDE 'IOCOM.INC/LIST'
778 INCLUDE 'FFRDAT.INC/LIST'
779 INCLUDE 'PARAMS.INC/LIST'
780
781 INTEGER IERR, IOSTAT, NFIELD
782 INTEGER IVALUE(MFIELD), KVALUE(MFIELD)
783 REAL RVALUE(MFIELD)
784 CHARACTER*(NFORM) CVALUE(MFIELD)
785 CHARACTER*(8) KEYWORD
786
787 C<><><><><><><><><><><>
788 C...BEGIN PROCEDURES...
789 C<><><><><><><><><><><>
790
791 IERR = 0
792
793 C ...Begin Scanning SOILMODEL control card data batch file
794 10 CALL FFRDFLDS( INASCI, NOUTFL, ' ', MFIELD, IOSTAT,
795 + NFIELD, KVALUE, CVALUE, IVALUE, RVALUE )
796
797 20 IF (IOSTAT.LT.0) THEN
798 C ...End Of File for SOILMODEL control card input file found
799 GOTO 100
800
801 ELSEIF (IOSTAT.GT.0) THEN
802 C ...Set the error flag, abort after EOF found
803 IERR = IERR + 1
804 C ...Read next record
805 GOTO 10
806
807 ELSEIF (IOSTAT.EQ.0) THEN
808 IF ( KVALUE(1).EQ.-1 .OR.
809 + (KVALUE(1).EQ.0 .AND.CVALUE(1).EQ.' ') ) THEN
810 C ...This is a comment line or a blank w/o information
811 C ...Read next record
812 GOTO 10
813
814 ELSEIF( KVALUE(1).EQ.0 .AND. (CVALUE(1)(:4).EQ.'*NUC' .OR.
815 + CVALUE(1)(:6).EQ.'*MODEL' .OR.
816 + CVALUE(1)(:5).EQ.'*SOIL' .OR.
817 + CVALUE(1)(:6).EQ.'*WATER') ) THEN
818 C ...Begin retrieving user data
819 KEYWORD = CVALUE(1)(2:9)
820 CALL RDPAR(IOSTAT, KEYWORD, NFIELD, KVALUE, CVALUE, IVALUE,
821 + RVALUE)
822 C ...Read next record
823 GOTO 10
824
825 ELSEIF( KVALUE(1).EQ.0.AND.CVALUE(1)(:4).EQ.'*END' )THEN
826 C ...Found END of SOILMODEL control file
827 C ...Abort reading user input
828 GOTO 100
829
830 ELSE
831 C ...Meaningless data found
832 C ...Read next record
833 GOTO 10
834
835 ENDDIF
836 ENDDIF
837
838 100 IF (IERR.GT.0) THEN
839 WRITE(NOUTFL,*) ' ***', IERR, ' ERRORS FOUND IN PROCTL ***'

```

soil.for;3

```

840      CALL QAABORT('PROCTL')
841      ENDIF
842      RETURN
843 C-----
844 C**** END OF SUBROUTINE PROCTL ****
845 C-----
846      END
847
848
849 *DECK RDPAR
850      SUBROUTINE RDPAR( IOSTAT, KEYWORD, NFIELD, KVALUE, CVALUE, IVALUE,
851 +                   RVALUE )
852 C*****
853 C****
854 C****      R_e_a_d   P_A_R   ameter names module
855 C****      -   -   -
856 C*****
857 C
858 C      PURPOSE:   Reads names of new SOILMOD input CONTROL parameters
859 C                  as stored (with values) in CDB files as matched with
860 C                  key user names (fixed or sampled)
861 C
862 C      AUTHOR:     Ron McCurley
863 C
864 C      UPDATED:    May 1999
865 C
866 C      CALLED BY:   PRCTRL
867 C
868 C      CALLS:       FREFLD
869 C                  QAABORT
870 C
871 C      ARGUMENTS:
872 C      ENTRY/
873 C      --common blocks
874 C      /COMMIO/ ($include 'GIL_COMMIO.INC')
875 C      ISCRAT = Device no. of PRESOILMOD scratch file
876 C      FILEIN = Device no. of PRESOILMOD input text file
877 C      NOUTFL = Device no. of diagnostics/debut output file
878 C
879 C      /PGENII/ ($include 'GIL_PGENII.INC')
880 C
881 C      --through subroutine call
882 C      MFIELD = Max. no. of data fields FFR can process
883 C      IOSTAT = ANSI FORTRAN I/O error flag
884 C      NFIELD = No. of data fields read by FFR
885 C      KVALUE = INTEGER array of types of data fields read by FFR.
886 C      CVALUE = CHARACTER array of data fields read by FFR.
887 C      IVALUE = INTEGER
888 C      RVALUE = REAL
889 C
890 C      LOCAL/
891 C      none
892 C
893 C      EXIT/
894 C      --common blocks
895 C      /I/ ($include 'I.INC') ???
896 C      ...REAL variables
897 C
898 C      --through subroutine call
899 C      MFIELD = Max. no. of data fields FFR can process
900 C      IOSTAT = ANSI FORTRAN I/O error flag
901 C      NFIELD = No. of data fields read by FFR
902 C      KVALUE = INTEGER array of types of data fields read by FFR.
903 C      CVALUE = CHARACTER array of data fields read by FFR.
904 C      IVALUE = INTEGER
905 C      RVALUE = REAL
906 C
907 C*****
908 C234567
909      IMPLICIT NONE
```

```

910 INCLUDE 'FFRDAT.INC/LIST'
911 INCLUDE 'IOCOM.INC/LIST'
912 INCLUDE 'PARAMS.INC/LIST'
913 INCLUDE 'NUCDAT.INC/LIST'
914 INCLUDE 'SOIL.INC/LIST'
915 INCLUDE 'WATER.INC/LIST'
916
917 INTEGER I, IERR, INUC, IOSTAT, K, NFIELD
918 INTEGER IVALUE(*), KVALUE(*)
919
920 REAL RVALUE(*), THETA
921
922 CHARACTER*(NFORM) CVALUE(*)
923 CHARACTER*(*) KEYWORD
924
925 C<><><><><><><><><><>
926 C...BEGIN PROCEDURES...
927 C<><><><><><><><><><>
928
929      IERR = 0
930 C      ...Read data for parameter replacement into new SOILMOD input control
931 C      file
932 10 CALL FFRDFLDS( INASCI, NOUTFL, ' ', MFIELD, IOSTAT,
933 +               NFIELD, KVALUE, CVALUE, IVALUE, RVALUE )
934
935 20 IF (IOSTAT.LT.0) THEN
936 C      ...End Of File for SOILMOD control card input file found
937       WRITE(NOUTFL,1001)
938       WRITE(NOUTFL,1002)
939       WRITE(NOUTFL,1001)
940       GO TO 100
941
942 ELSEIF (IOSTAT.GT.0) THEN
943 C      ...Set the error flag, abort after EOF found
944       IERR = IERR + 1
945 C      ...Read next record
946       GOTO 100
947
948 ELSEIF (IOSTAT.EQ.0) THEN
949       IF (KEYWORD(1:3).EQ.'NUC') THEN
950 C          ...get nuclide names
951           IF ( KVALUE(1).EQ.-1 .OR.
952 +             {KVALUE(1).EQ.0 .AND.CVALUE(1).EQ.'!'} ) THEN
953 C              ...This is a comment line or a blank w/o information
954 C              ...Read next record
955               GOTO 10
956
957 ELSEIF(KVALUE(1).EQ.0.AND.CVALUE(1)(:4).EQ.'NAME' .OR.
958 +       CVALUE(1)(1:4).EQ.'name' ) THEN
959
960       DO 30 I=2,NFIELD
961         INUC = I-1
962         NAMNUC(INUC)=CVALUE(I)(1:8)
963 30    CONTINUE
964         NUMNUC = NFIELD-1
965       ELSE
966 C          ...Found meaningless data
967         WRITE(NOUTFL,*)'***found unexpected meaningless data ',
968 +                   'may be a problem in user input file!***'
969 C*        NAME_NUC = .TRUE.
970
971       ENDIF
972 C      ...return to read next keyword
973       GOTO 999
974 ELSEIF (KEYWORD(1:5).EQ.'MODEL') THEN
975       IF ( KVALUE(1).EQ.-1 .OR.
976 +       {KVALUE(1).EQ.0 .AND.CVALUE(1).EQ.'!'} ) THEN
977 C          ...This is a comment line or a blank w/o information
978 C          ...Read next record
979       GOTO 10

```

```

980      ELSEIF ( KVALUE(1).EQ.0 ) THEN
981 C      ...Begin retrieving soil parameter data
982 C      loop over remaining words in this field
983      IF(CVALUE(1)(1:5).EQ.'WATER') MODEL = CVALUE(2)(1:8)
984      ENDIF
985      GOTO 999
986      ELSEIF (KEYWORD(1:4).EQ.'SOIL') THEN
987      IF ( KVALUE(1).EQ.-1 .OR.
988      +      (KVALUE(1).EQ.0 .AND.CVALUE(1).EQ.'!')) THEN
989 C      ...This is a comment line or a blank w/o information
990 C      ...Read next record
991      GOTO 10
992      ELSEIF ( KVALUE(1).EQ.0 ) THEN
993 C      ...Begin retrieving soil parameter data
994 C      loop over remaining words in this field
995      DO 40 I=1,NFIELD,2
996      IF(KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'TYPE' .OR.
997      +      CVALUE(I)(:4).EQ.'type') THEN
998      SOILCAT(1:4) = CVALUE(I+1)
999      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'DENS' .OR.
1000      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'dens') THEN
1001      RHOS = RVALUE(I+1)
1002      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:5).EQ.'POROS' .OR.
1003      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:5).EQ.'poros') THEN
1004      POROSITY = RVALUE(I+1)
1005      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:5).EQ.'DEPTH' .OR.
1006      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:5).EQ.'depth') THEN
1007      DEPTHS = RVALUE(I+1)
1008      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:5).EQ.'WATER' .OR.
1009      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:5).EQ.'water') THEN
1010      THETA = RVALUE(I+1)
1011      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'UNIT' .OR.
1012      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'unit') THEN
1013      UNITS_SOIL = CVALUE(I+1)(1:8)
1014      ELSE
1015 C      ...Found meaningless data
1016      WRITE(NOUTFL,*) '***found unexpected meaningless data',
1017      +      'may be a problem in user input file!***'
1018      ENDIF
1019      40      CONTINUE
1020 C      ...
1021      ENDIF
1022      GOTO 100
1023
1024      ELSEIF (KEYWORD(1:5).EQ.'WATER') THEN
1025 C      ...Begin retrieving water parameter data
1026 C      loop over remaining words in this field
1027      DO 60 I=1,NFIELD,2
1028      IF(KVALUE(I).EQ.0.AND.CVALUE(I)(:6).EQ.'PRECIP' .OR.
1029      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:6).EQ.'precip') THEN
1030      PRECIP = RVALUE(I+1)
1031      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'IRRI' .OR.
1032      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'irri') THEN
1033      IRRIG = RVALUE(I+1)
1034      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'EVAP' .OR.
1035      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'evap') THEN
1036      ET = RVALUE(I+1)
1037      ELSEIF(KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'UNIT' .OR.
1038      +      KVALUE(I).EQ.0.AND.CVALUE(I)(:4).EQ.'unit') THEN
1039      UNITS_H2O = CVALUE(I+1)(1:8)
1040      ELSE
1041 C      ...Found meaningless data
1042      WRITE(NOUTFL,*) '***found unexpected meaningless data',
1043      +      'may be a problem in user input file!***'
1044      ENDIF
1045      60      CONTINUE
1046 C      ...
1047      GOTO 999
1048      ELSE
1049 C      ...Found meaningless data

```


soil.for;3

```
1050      WRITE(NOUTFL,*)' ***found unexpected meaningless data ',
1051      +      'may be a problem in user input file!***'
1052 C      ...Read next record
1053      GOTO 10
1054      ENDIF
1055 C      ...Read next record
1056      GOTO 10
1057      ENDIF
1058
1059 100  CONTINUE
1060      IF (SOILCAT(1:4).EQ.'SILT') THETA1 = THETA
1061      IF (SOILCAT(1:4).EQ.'CLAY') THETA2 = THETA
1062      IF (SOILCAT(1:4).EQ.'SAND') THETA3 = THETA
1063      IF (SOILCAT(1:4).EQ.'ORGA') THETA4 = THETA
1064      IF (SOILCAT(1:4).EQ.'BAES') THETA4 = THETA
1065
1066 C
1067 999  CONTINUE
1068      RETURN
1069 1001 FORMAT('*****')
1070 1002 FORMAT('WARNING! '/
1071      +      'Encountered unexpected end of user input'/
1072      +      'May be bad file! ')
1073 C-----
1074 C**** END OF SUBROUTINE RDPAR ****
1075 C-----
1076      END
1077
1078
1079 *DECK,TYPRQS
1080      SUBROUTINE TYPRQS( PROMPT, ISTRNG )
1081 C*****
1082 C
1083 C  PURPOSE:      Outputs a request for a character string using PROMPT
1084 C                and then inputs the character string (ISTRNG) in an
1085 C                interactive session.
1086 C
1087 C  AUTHOR:       Rob Rechard
1088 C
1089 C  UPDATED:      June 1985
1090 C                July 1987      --Ginger Wilkinson
1091 C                15 February, 1989 --Jonathan S. Rath made more generic
1092 C
1093 C  CALLED BY:    PREPRO
1094 C
1095 C  ARGUMENTS:
1096 C  ENTRY/
1097 C      --through subroutine call
1098 C      PROMPT = Message to print on the screen
1099 C
1100 C  EXIT/
1101 C      --subroutine call
1102 C      ISTRNG = Character string read
1103 C
1104 C*****
1105 C234567
1106      IMPLICIT NONE
1107      CHARACTER(*) ISTRNG, PROMPT
1108      WRITE(*,1000)PROMPT
1109      10 READ(*,'(A)',END=20,ERR=30) ISTRNG
1110      RETURN
1111
1112      20 WRITE(*,2000)
1113      GOTO 10
1114      30 WRITE(*,3000)
1115      GOTO 10
1116
1117 C----- F O R M A T   S T A T E M E N T S -----
1118 1000 FORMAT(A,' >>')
1119 2000 FORMAT(' ***NO DATA--TRY AGAIN***')
```

```

1120 3000 FORMAT(' ***BAD CHARACTER STRING--TRY AGAIN***')
1121 C-----
1122 C**** END OF SUBROUTINE TYPRQS ****
1123 C-----
1124     END
1125
1126 *DECK,WELCOM
1127     SUBROUTINE WELCOM
1128 C*****
1129 C
1130 C PURPOSE:      Produces Instructions for main program usage
1131 C
1132 C PROGRAMMER:   Jonathan S. Rath
1133 C
1134 C UPDATED:      24 May, 1989 --First Ed.
1135 C
1136 C CALLED BY:    PREPRO
1137 C
1138 C CALLS:        QABANNER
1139 C
1140 C ARGUMENTS:
1141 C ENTRY/
1142 C     --common blocks
1143 C
1144 C /QACOMMON/
1145 C     PROGRM = The program name (CHAR*12)
1146 C     PVERSN = The program version number (CHAR*8)
1147 C
1148 C /L1/ Contains Line 1 of a 3-line program discription written out
1149 C         following the program banner
1150 C /L2/ Contains Line 2 of a 3-line program discription written out
1151 C         following the program banner
1152 C /L3/ Contains Line 3 of a 3-line program discription written out
1153 C         following the program banner
1154 C
1155 C LOCAL/
1156 C     IOUT = Device number of output file
1157 C
1158 C EXIT/
1159 C     none
1160 C
1161 C*****
1162 C234567
1163
1164     IMPLICIT NONE
1165
1166     INCLUDE 'CAMCON_COMMON.INC/list'
1167
1168     INTEGER IOUT
1169     CHARACTER*1 CHAR
1170     CHARACTER*80 LINE1,LIN2,LIN3
1171     COMMON /L1/ LINE1
1172     COMMON /L2/ LIN2
1173     COMMON /L3/ LIN3
1174     DATA IOUT/5/
1175
1176 C<><><><><><><><><><>
1177 C...Begin Procedures...
1178 C<><><><><><><><><><>
1179
1180 OPEN(IOUT,FILE='SYS$OUTPUT',FORM='FORMATTED',STATUS='UNKNOWN')
1181 CALL QABANNER(IOUT,LIN1,LIN2,LIN3)
1182 WRITE(IOUT,1000)
1183 ...Abort PROGRAM execution ?
1184 WRITE(IOUT,1200)PROGRM,PVERSN
1185 READ(IOUT,'(A)')CHAR
1186 IF(CHAR.NE.'N')THEN
1187 STOP ***** USER ABORTED EXECUTION IN SUBROUTINE WELCOM *****
1188 ENDF
1189

```

soil.for;3

```
1190 CLOSE(IOUT)
1191 RETURN
1192 C
1193 C----- F O R M A T   S T A T E M E N T S -----
1194 C
1195 1000 FORMAT(///
1196 + '*****'/
1197 + '    PREINFIL: PRE-processor for INFIL input control file    '/
1198 + '*****'///
1199 + ' Following are prompts for'//
1200 + '    (1) Filename of PREINFIL control input file'//
1201 + '    (2) Filename of Computational Data Base to be read'//
1202 + '    (3) Filename of Template INFIL input control file '/
1203 + '    (3) Filename of PREINFIL generated INFIL input file'//
1204 + '    (4) (OPTIONAL) Filename of PREINFIL diagnostics/debug'//
1205 + '    file'//,
1206 + '*****'/)
1207
1208 1200 FORMAT(/79('*'),///1X,'To CONTINUE program ',A,' V',A,' press',
1209 + ' the RETURN key.',/1X,'To ABORT program, type the word',
1210 + ' ABORT')
1211 C
1212 C-----
1213 C**** END OF SUBROUTINE WELCOM ****
1214 C-----
1215 END
end
```